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Arthur T. Benjamin is Professor of Mathematics at Harvey Mudd College, where he has taught since 1989. He earned a Ph.D. in Mathematical Sciences from Johns Hopkins University. The Mathematical Association of America honored him with national awards for distinguished teachingin 1999 and 2000 and named him the George Pólya Lecturer for 2006–08.

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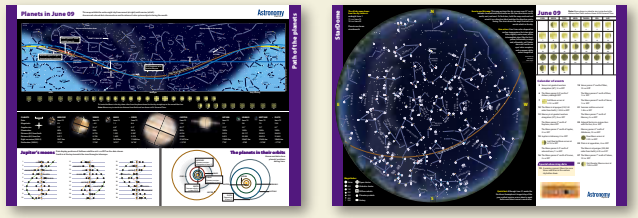

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UNIVERSE
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Illustrated celestial sphere: How we see the sky

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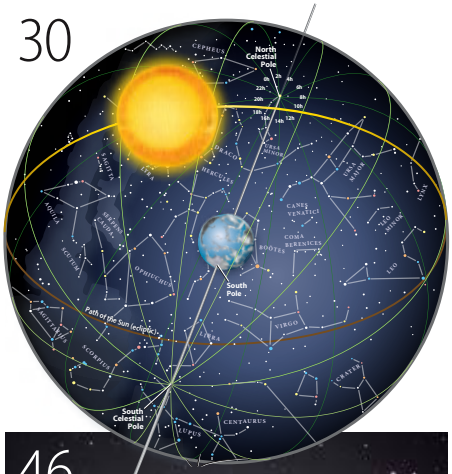

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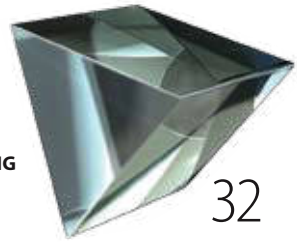

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Join *Astronomy* magazine on a Kenyan safari

by David J. Eicher

From January 8–19, 2010, *Astronomy* magazine will partner with Melita Thorpe of MWT Associates to escort amateur astronomers to a spectacular annular eclipse that will last more than 8 minutes. We'll journey to Kenya on this Great Rift Valley Annular Eclipse and Kenya Safari trip.

Some consider the Great Rift Valley, which runs through Kenya, to be the cradle of humanity, and it is justifiably one of the world's best-organized safari destinations in Africa. Travelers can see many animals, including lions, leopards, elephants, and rhinos. It offers 1,200 species of birds, including flamingos standing in a shimmering pink mass at Lake Nakuru, where we'll view the January 15 eclipse.

A lion perches atop a boulder at the Maasai Mara, Kenya's best game reserve. Dennis Mammana/MWT Associates

I'll be pleased to accompany *Astronomy* magazine readers on our expedition, along with famed astroimager Dennis Mammana. We'll set off from the United States to London and on to Nairobi, where we'll stay at the Norfolk Hotel, the same hotel Theodore Roosevelt used while hunting Kenyan game.

From Nairobi, we'll venture through the green highlands and coffee plantations to the Samburu Game Reserve on the edge of the Ewaso Niro River. We will then journey to Lake Nakuru National Park, renowned for its bird sanctuary as well as rhinos and giraffes.

We'll get up on eclipse morning for some bird watching, keeping an eye on the larger critters before the annular eclipse washes over the landscape and we soak in 8 minutes, 25 seconds of annularity.

The day after the eclipse, we'll journey back to Nairobi and fly to the country's best game reserve, the Maasai Mara. Classic safari-style luxury tents with ensuite baths overlook the surrounding plain, laden with wildlife.

Cheetahs zoom across the plain as giraffes, buffaloes, wildebeests, and elephants roam. Even baboons range the Kenyan countryside.

Perhaps the most majestic of the many species we will see is the lion, king of the plains. Following a few days at the Maasai Mara we'll fly back to Nairobi and on home. It will be the grand adventure of a lifetime. I hope you will be able to join me, Dennis, Melita, and the rest of the crew on what no doubt will be a spectacular trip. For more information, please see: www.Astronomy.com/tours.

Yours truly,

David J. Eicher
Editor

Astronomy

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Dream observatory

Recently I designed and built a unique observatory — it's also a home theater and a tornado shelter designed to take a direct hit from an F5 tornado. It's fully automated with a hydraulically driven roof that weighs 20,571 pounds (9,331 kilograms). The roof lifts up and then rolls away to the ends of the tracks. This leaves the user sitting inside four walls, each 14 feet (4.3 meters) high but open to the night sky.

The observatory has two telescopes (a 16-inch Ritchey-Chrétien and a 6-inch refractor) for viewing everything from the solar system to deep space. The chair that the observer sits in is hydraulically driven. I designed this observatory so that the user would have no physical work to do from the beginning to the end of an observing session. One needs only to climb into the hydraulic chair and then push a few switches. The building has a big-screen TV in the top corner for viewing objects through a camera that is installed on either of the two telescopes.

The facility is climate-controlled to protect the telescopes and electrical equipment from humidity. Additionally, I equipped the building with a 7.1 surround-sound system.

A hydraulic two-person chair allows the user to observe in comfort. Joseph Aymond

Joseph Aymond designed his observatory to withstand an F5 tornado. In this image, the roof is rolling to the right end of the tracks.

Joseph Aymond

I completed the observatory in February 2007 and the web site (www.ultimateprivateobservatory.com) in January 2009. The web site has several hundred construction photos along with details regarding the building. I made by hand a large percentage of the parts needed to build this facility. A 1-hour video explaining every aspect of the construction is available on the web site. **— Joseph Aymond,** Washington Parish, Louisiana

Pronunciation guide?

After reading Bob Berman's "Betelgeuse: the next banana split" (February 2009), I must say that the pronunciation of Betelgeuse is for me one of the mysteries of astronomy. I can think of at least four pronunciations, and I originally used that of my sixth-grade science teacher who pronounced it bay-tel-jeez (with a hard "g" sound). In later life I began pronouncing it bay-tel-joos, but Bob Berman is no doubt correct with betl-joos.

Is there an authority we can turn to for the pronunciation of astronomy-related words and names? I recall a star party many years ago when I heard some snickers after I called M13 a globe-u-lar cluster. It seemed perfectly logical to me at the time. And what about the "Kuiper" Belt? I have heard it pronounced Keep-er and Kipe-er and Kwee-per! How did Gerard pronounce it?

Perhaps someday Bob Berman could devote a column to the correct pronunciation of the words and especially the names used in astronomical literature. It would be written, of course, in his entertaining style. **— Jim McCormick,** Victor, Idaho

Give Galileo his due

As we celebrate the 400th anniversary of Galileo pointing his telescope at the Moon, how about the International Astronomical Union loosening its collective collar and assigning him a respectable crater instead of the dinky hole in the ground that now bears his name? Copernicus, Tycho, and Kepler got respect. Galileo got a ho-hum 10-mile-wide (16 kilometers) indentation and a rille.

Frankly, we should be outraged that this insult has gone so long uncorrected. Will Theophilus or Archimedes really care if we give our man his due? Let's make it right in 2009! **— Bob Kerr,** Bloomington, Minnesota

Writing to reduce lighting

Senior Editor Michael E. Bakich's "Can we win the war against light pollution?" from the February 2009 issue was both well-written and informative. On behalf of the Peterborough Astronomical Association, I have been leading the fight for light pollution abatement in the City and County of Peterborough for 5 years. This city of 75,000 people 60 miles (100 km) northeast of Toronto has started replacing failed streetlights with full-cutoff fixtures with flat lenses and is requiring all new streetlights to also be full-cutoff lights.

To help others with the fight, I wrote an article in the June 2007 issue of the *Journal of the Royal Astronomical Society of Canada* (RASC) titled "Reclaiming Our Night Skies: Fighting Light Pollution." It is not as daunting a task as one might suspect. It just requires some persistence on the part of a few dedicated people. **— Mark Coady,** Bridgenorth, Ontario

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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GETTING TO KNOW

David J. Eicher

David **Levy**

Contributing Editor of *Astronomy* and one of the most successful comet discoverers in history

Most memorable comet discovery: This one is hard to answer. The comets are like my children — I can't play favorites. The first and most recent ones are the most impressive in my memory right now. I especially treasure a recent discovery, which took place on Yom Kippur morning in 2008, the holiest day in the Jewish calendar. It reminds me of the joke about the rabbi who took Yom Kippur off to play golf and got a hole in one. Who was he going to tell? In my case, it was no joke. The observatory is my synagogue; I love that place. I have no problem using it on that special day.

Favorite topic for your radio show: Singing astronomy songs with Peter Jedicke — one of Canada's most well-known amateur astronomers — is right up there. It brings me back to the late 1970s when I first earned his friendship.

Biggest goal for the Jarnac Comet Survey: We obviously want to discover more comets!

Greatest observing experience: The first minute of every observing session, when I go out and look up at the stars.

Favorite sky target to show beginners: The Moon because it's a place, not just a dot in the sky. You can imagine climbing a lunar mountain or crawling into a crater.

Favorite deep-sky target observed: The Double Cluster in Perseus (open clusters NGC 884 and NGC 869), from a dark sky during the summer of 1968. Late at night August 20 of that year, I was observing with two colleagues at Camp Minnowbrook, near Lake Placid, New York, deep within the Adirondacks. We set my 6-inch f/4 reflector up by the old teahouse building on the shore and turned it to the Double Cluster. The stars were sparkling against an almost black background of deep space. It was unforgettable.

Proudest moment in your life: It took place during a visit from my then-girlfriend Wendee in 1995. After a serious conversation, she said: "I don't know if we will ever get together. But if you don't open up your heart to somebody, when you're an old man, all you'll have is your ice comets to snuggle up to." That was the moment I fell in love with Wendee. We were married 2 years later.

"The comets are like my children — I can't play favorites."

Paolo Candy/Cimini Astronomical Observatory

Astrofascinations

What fascinates you most about Saturn and its moons?

Before all else, I continue to be fascinated with the beauty, spectacle, and magnificence of the entire Saturn system. It moves me in the same way it moves the casual observer, and I find myself incredibly thankful to be alive at a time when humanity had the means and the will to make this journey possible.

Beyond that, I'm fascinated with the scientific richness that abounds in this section of the solar system. By studying Saturn, we can witness processes at work today that were similar to those responsible for configuring the solar system and for producing the habitable environment on the surface of our own planet. In Saturn's rings and satellite system, we can see how the very beginning stages of the development and orbital arrangements of the Sun's planets might have unfolded.

In the end, if what we seek is to understand how we and the planet we live on are connected to the greater universal scheme of things, then you could hardly pick a better place to go than Saturn.

Courtesy Carolyn Porco

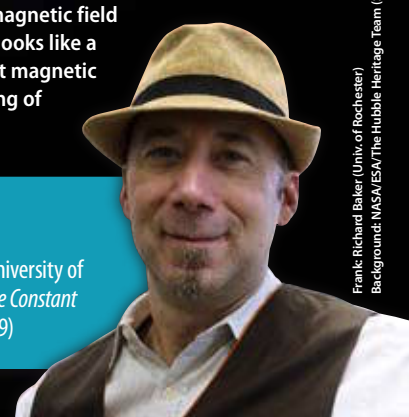
Carolyn **Porco**

Leader of the Cassini Imaging Science team and consultant for the 2009 *Star Trek* movie

Astroideas *Where is the study of planetary nebulae going?*

In the field of planetary nebulae, we are undergoing a paradigm shift. The old idea was that all Sun-like stars became planetary nebulae. At the end of the star's lifetime, it swells and becomes a red giant. The red giant then undergoes heavy mass-loss, which strips most of the star's mass until it becomes a naked, hot core. The fast wind from the core blows into the slower-moving material previously shed by the red giant and inflates a planetary nebula.

The new idea is that all Sun-like stars *do not* become planetary nebulae. Instead, only binary stars orbiting close enough to each other for them to gravitationally interact and exchange mass create the planetary nebula phenomenon. The interaction generates a strong magnetic field on one of the stars. This magnetic field powers a collimated wind — which looks like a jet — from one of the stars. And that magnetic jet actually does most of the sculpting of the planetary nebula.



Frank: Richard Baker (Univ. of Rochester)
Background: NASA/ESA/The Hubble Heritage Team (STScI/AURA)

Adam **Frank**

Professor of physics and astronomy, University of Rochester, New York, and author of *The Constant Fire* (University of California Press, 2009)

Astro**influences** *How do you get kids excited about astronomy?*

Courtesy Laura Danly

Laura **Danly**

Curator of the Griffith Observatory in Los Angeles

Kids are naturally curious. A science educator's job is, first, to do no harm and, second, to build on children's natural enthusiasm for the world — and sky — around them.

Doing no harm means taking children seriously and responding to their questions earnestly. Don't do anything to shame them for their lack of knowledge or for their enthusiasm. And speak to them in a way they can understand. It helps to link the ideas with everyday experiences.

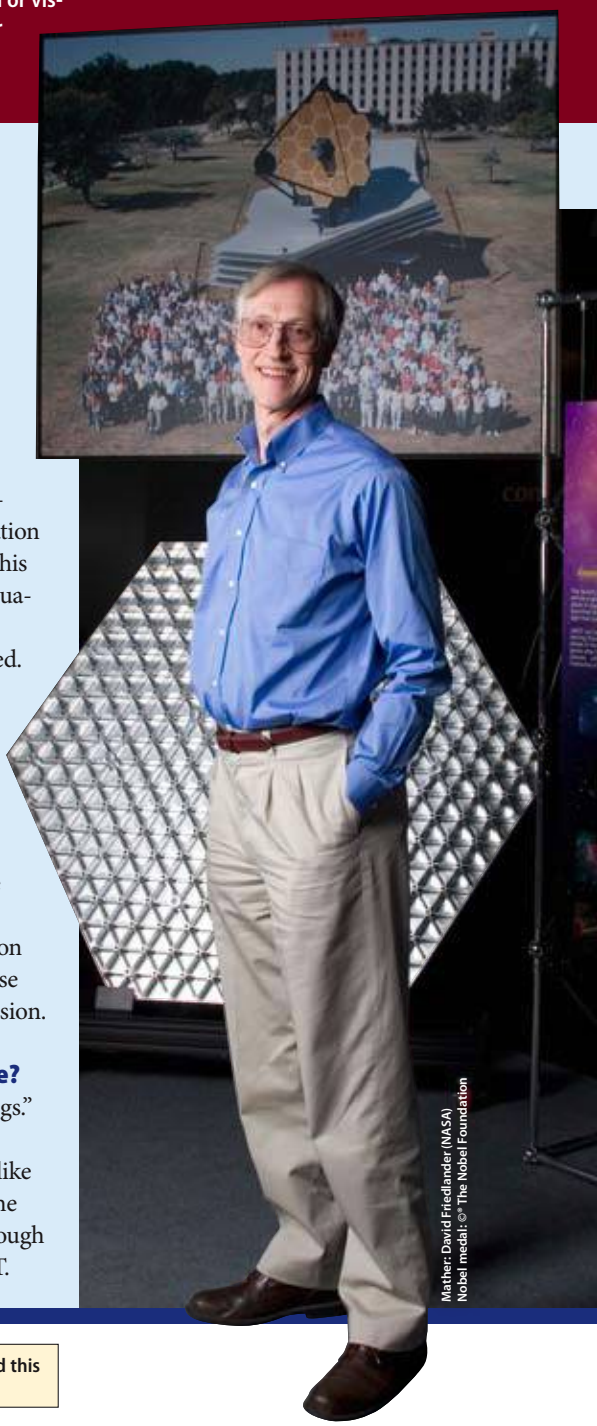
It can be tempting — especially if you aren't 100 percent sure of the answer — to respond to a child with something that sounds convincing but doesn't actually make sense. If children hear explanations they don't understand but think they should, a lot of damage can be done. The child thinks, "I just can't understand this stuff." Or, to paraphrase an old talking Barbie, "Science is hard." (The next line: "Let's go shopping!") If you aren't confident about an answer, try, "I don't know; let's find out together."

The best way to nurture a love for astronomy is to put kids in the path of as many astronomy experiences as possible. Take them to a dark-sky site (and be sure to have hot chocolate!). Go to museums and planetaria. In Los Angeles, for example, few things are as memorable for a youngster as a trip up Mount Hollywood to Griffith Observatory to see the sparkling city views, look through a telescope, and see a planetarium show. Purchase fully illustrated picture books about astronomy. Don't print out lower quality images from the Web from a home computer. The goal is to overwhelm them with the visual experience. Watch NASA launches and landings. Go outside at night and look for the Moon or visible planets. Whatever it is, it should be FUN. The rest will follow.

OUR TURN

John **Mather**

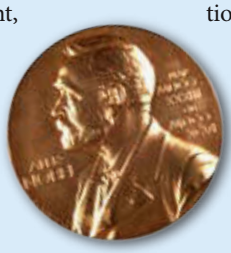
Senior project scientist for the James Webb Space Telescope (JWST) and a 2006 Nobel Laureate in Physics for his work with NASA's Cosmic Background Explorer (COBE)



Mather: David Friedlander (NASA)
Nobel medal: © The Nobel Foundation

What were your first thoughts after you won the Nobel Prize?

How am I going to get the whole COBE team to Stockholm? With my co-recipient, George Smoot of the University of California at Berkeley, we managed to get enough tickets for the whole team to be able to attend.



Also, my life has changed forever. My basic approach has been to stick with my technical work while taking on opportunities to communicate with the public about the beauty of scientific discovery. Recently, I have cut back on my travels and speaking engagements to concentrate more on completing the JWST.

What is your biggest expectation for next-generation cosmic microwave background (CMB) spacecraft?

We are all expecting that the European Space Agency's Planck mission will extend the discoveries of COBE, the Wilkinson Microwave Anisotropy Probe (WMAP), and ground-based observations. Planck will measure shorter wavelengths than COBE or WMAP, enabling better angular resolution and sensitivity. This additional sensitivity may reveal new features of the early universe.

The CMB is the remnant afterglow of the Big Bang. WMAP has already shown that the CMB light is slightly polarized — the electric fields have a preferred orientation that varies across the sky. Correlation of this pattern with the CMB's temperature fluctuations has been interpreted to show when the universe was re-ionized.

The Planck mission will test theories of the early universe. For example, if the Big Bang produced a spectrum of gravitational waves, then the traces may be detectable in the polarization of the CMB. This detection would help prove inflation theory, which states that a fraction of a second after the Big Bang, the universe experienced a brief period of hyperexpansion.

What do you want your legacy to be?

It will not be, "He went to a lot of meetings." Among other things, I would like to be remembered for scientific achievements like the COBE discoveries and for enabling the work of thousands of other scientists through developing new equipment like the JWST.

To learn more about the people featured this month, visit www.Astronomy.com/toc.

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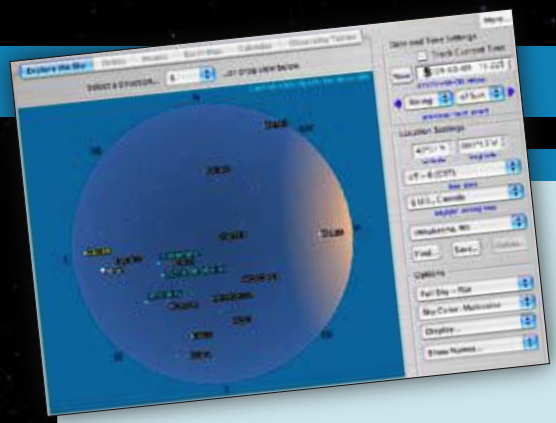

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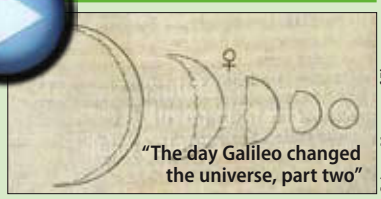

"The day Galileo changed the universe, part two"

Science Museum of Florence

Featured Video
In "The day Galileo changed the universe, part two," *Astronomy* magazine Editor David J. Eicher talks about Galileo and his early use of the telescope.

Podcasts
Senior Editor Michael E. Bakich's weekly series — at www.Astronomy.com/Podcast — helps you find three objects or sky events you can see.

OBSERVING TOOLS

The Sky this Month
Read the complete version of June's "The Sky this Month" online.

Star Atlas
Zoom in and out on 24 sky maps with this interactive star atlas.

Sky Events Calendar
You'll find upcoming delights for both day and night observing. Take a moment and browse for upcoming events. You may search the events by category and date.

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Globular cluster NGC 3201

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Strange Universe

by Bob Berman

How much solstice can you handle?

Test family and friends with summer solstice trivia.

June, of course, brings the summer solstice. It's one of the few links between sky and Earth that still makes the evening news. Ask friends what happens June 21, and they're likely to get it right, mostly. Longest day — check. Sun highest up — check. Sun moves through the sky along its most curving path — hmm, what? That one's not widely known.

Still, people do pretty well with the summer solstice. Yet most folks fail miserably when it comes to everything else about the sky. Even those with Ph.Ds bomb when asked the stone-simple sky stuff every village idiot would have known 200 years ago. Go ahead, test your friends. As the Sun is setting in the Northern Hemisphere, does it move straight down, down and to the left, or down to the right? Most get this wrong. A century ago, everyone would have picked the latter choice without a moment's hesitation.

Why is the world so sky-stupid? Perhaps modern people are less observant. More finish college than ever before, yet you don't need a classroom to learn the basics of nature. It stares you in the face. But if you're not looking, you won't see it.

We could offer a hundred pages about the solstice and its fascinating history, mythology, and science, but few could handle it. Even many astronomers prefer entertaining gee-whiz-type information rather than detailed, technical facts. Which of these revelations do you find more interesting? (a) Researchers found a pulsar 4,600 light-years away that spins 3 times a second and emits only gamma rays; or (b) Shadows of lunar mountains creep along crater floors at 10 mph (16 km/h), the same speed as a jogger.

Most of us would pick (b) even though the information is centuries old, while the other discovery is brand new. That's because it's more fun to learn about things with which we're already somewhat familiar. We enjoy gossip about friends, not strangers. Fact B combines everyday concepts like shadows and jogging.

Here's a quiz question you'll probably enjoy. What kind of energy does the Sun emit most strongly? (a) Heat; (b) Ultraviolet energy; (c) Gamma rays; or (d) Green light. Unlike the general public, you're already familiar with the electromagnetic spectrum. So, the issue will sound interesting, especially if the answer involves something familiar rather than exotic. In this case, it's ordinary green light. When we realize that green is the wavelength most prevalent in starlight and that our eyes, too, are maximally sensitive to it, well, we can relate to this kind of stuff.

Choosing which solstice morsels to share requires that you know your audience.

Another example: Which of these happens in about a month? (a) The Sun completes one rotation; (b) The Moon rotates once on its axis; (c) The Moon revolves once around Earth; (d) The Sun occupies one zodiac constellation; or (e) All of the above. Yep, the answer is (e). Celestially speaking, a month is surprisingly consequential.

Last one: How long does it take the Sun or Moon to move its own width as it crosses the sky? Answer: 2 minutes — the duration of the sunset in the tropics.

Notice that all these involve light or time, the key players in the solstice. Using the solstice to pique others' interest in the sky, we'd ideally tell them things they don't already know, but which they can relate to. That's my job on this page and yours when you hook family or friends into astronomy. You alone know what they can handle. OK, here are a few more goodies:

- The word *solstice* comes from the two Latin words "sun" and "stoppage." Makes sense: The Sun stops moving north that day.
- The June solstice Sun hovers straight over the Tropic of Cancer, just south of Key West, Florida.
- The summer solstice is when the Sun reaches its highest point of the year, but it's getting *less high* over time. That's because Earth's tilt is decreasing.
- The solstice is when the Sun is *lowest* in the sky for those at the equator.
- In India, the summer solstice marks the end of a 6-month period when spiritual growth is supposedly easiest. Too bad, you blew it.
- On the summer solstice, the Sun rises farthest left on the horizon and sets at its rightmost possible spot. Sunlight strikes places in rooms that get illuminated at no other time.
- In ancient Greece, the solstitial Sun happened in Cancer. But it moved into Gemini around the time of Christ. In 1989, it shifted into Taurus, where it will remain until the fifth millennium.

Choosing which solstice morsels to share requires that you know your audience. It may be the best-known sky event, but everyone has their own unique attention span and appetite for information. Maybe that's why TV announcers merely give it 2 seconds:

"It's the start of summer!"

Observing Basics

by Glenn Chaple

An imperfect Moon

Get acquainted with our satellite's many mountains and craters.

What was the first sky object you ever targeted with a telescope? If you're typical of most backyard astronomers, you chose the Moon. Brightest and easiest to find of the night sky's many offerings, Earth's only natural satellite is the perfect destination for that maiden telescopic voyage. Four centuries ago (November 30, 1609, by most accounts), Galileo launched his astronomical career by observing the Moon with a homebuilt refractor.

He wasn't the first. The English astronomer Thomas Harriot earned that distinction by directing a telescope moonward 4 months earlier. However, Harriot didn't immediately publish a description of what he saw.

When Galileo turned his attention to the Moon, he expected to capture a close-up view of divine perfection. The prevalent philosophical and religious teachings of his time stated in no uncertain terms that the Moon, being a heavenly body, was perfectly spherical and flawlessly smooth. To be sure, dark regions could be seen with the unaided eye, but these were dismissed as areas of differing density. What Galileo saw as he peered into the eyepiece was unexpected and unsettling, prompting him to continue observing the Moon well into December 1609.

In *Sidereus Nuncius* ("Starry Messenger"), published several months later, Galileo wrote: "I have been led to the opinion and conviction that the surface of the Moon is not smooth, uniform, and precisely spherical as a great number of philosophers believe it (and the other heavenly bodies) to be, but is uneven, rough, and full of cavities and prominences, being not unlike the face of the earth." Galileo had discovered several mountains and valleys and innumerable craters on the Moon. The cosmos had lost perfection.

The First Quarter Moon is the perfect destination for that maiden telescopic voyage. Viewing along the terminator highlights the cratered lunar surface. John Vrabec

The Moon's imperfections are what make it such a compelling telescopic sight. The lunar landscape, replete with majestic peaks jutting miles above the cratered surface, presents observers with an unforgettable vista. No telescopic scene except, perhaps, Saturn is more likely to evoke a gasp of awe from the first-time sky gazer.

One of the goals of the current International Year of Astronomy (IYA2009) is to promote astronomy through public outreach programs. The most popular outreach vehicle is the public star party. I strongly urge any individual or group planning such an event to stage it on an evening when the Moon is available (and submit it to www.Astronomy.com/events). The best time is a 1-week observing window centered on the first quarter (evening "half Moon") phase. Viewing along the terminator — the line that separates the light from the dark hemispheres of the Moon — highlights the cratered lunar surface. Upcoming First Quarter Moons occur the evenings of May 30, June 28, and July 28.

There are a number of useful Internet resources for those of you who are happily afflicted with Moon Madness. Two of my favorite Moon-related web sites are Lunar Republic (www.lunarrepublic.com) and Inconstant Moon (www.inconstantmoon.com). Each site offers a free Moon atlas in which numerous key lunar features are identified. For those of you who want to delve more deeply into the story of Galileo's observations of the Moon, try Tom Pope's web site at www.pacifier.com/~tpope/Moon_Page.htm.

And, of course, the StarDome pullout at the center of each month's issue of *Astronomy* provides a monthly Moon phase calendar for your convenience.

It's unfortunate that the Moon is considered a friend of the beginner but an expert's enemy. After the Moon's novelty wears off, we tend to bypass it in favor of the planets, eventually moving on to deep-sky objects. It's then that the Moon assumes the role of an unwelcome invader whose brilliant light floods the heavens with nature's version of light pollution.

If you're a novice backyard astronomer, take your telescope outside and enjoy the thrill of a lunar voyage. Start by identifying the Moon's dark maria, or seas, and then move on to some of the larger craters. If you're one of those veterans who grumble whenever moonlight prevents you from touring the Coma-Virgo Galaxy Cluster, put aside the charts and turn your attention to the Moon. Rediscover the excitement you felt when you first laid eyes on its cratered terrain. Reacquaint yourself with an old friend!

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: a Galileo observing technique you *don't* want to repeat! Clear skies!

Find a First Quarter Moon observing guide at www.Astronomy.com/toc.

Evening Stars
by David H. Levy

A David Levy sky

All it takes is a dark sky to begin a lifelong interest in astronomy.

Almost 40 years ago, Joan-Ellen Rosenthal was riding in a car down a lonely country road near Enid, Oklahoma, with her then-husband. They were lost. "We know we have to go south," Joan said to her husband. He stopped the car, and Joan got out, looked around, then got back in. "I just found the Big Dipper. From there I found the North Star. We have to take the next right to head south." Her husband was flabbergasted. "Only you know how to navigate by the stars," he said as they were on their way.

It is amazing how few people know where the North Star is. Many assume that it's either the brightest star in the sky or the brightest star near the zenith. And in our age of GPS positioning, why bother looking at the stars anyway?

There is one simple answer: On a clear night, the stars call to us. They offer an easy, time-honored approach to getting your bearings, one that doesn't cost a cent and can be a lot of fun. Learning the stars requires no math, no telescope, and only a little reading. But it asks for patience and passion.

Of all years, 2009 is perhaps more important than most to start an interest in astronomy. This is, after all, the International Year of Astronomy. It is a celebration not of any real discovery, but of a decision Galileo made. After hearing of the invention of a two-lensed spyglass in Holland, Galileo chose to make a better one, increase its magnification, and then turn it toward the heavens. His great discoveries of the moons of Jupiter and the phases of Venus came in 1610. These discoveries are a consequence of Galileo's decision to point a telescope at the sky, and they changed science forever.

As we dignify Galileo, we also honor you — especially if you are using this momentous year to launch your own interest and delight in the night sky. What could be better than a first night under the stars? That first look can be priceless. You don't know a single one of the stars, which means that the whole sky is open to you like the pages of an ancient book. Even in this age of big government and homeland security, no law requires us to follow a particular prescription for constellations. The long-necked Swan that is traditionally Cygnus can be, in your eyes, an office tower, a magazine office, a school, or even the house you live in. This is the time to let your imagination roam; more than anything else, this first night out is a night of discovery and fun.

Joan-Ellen Rosenthal, photographed about 10 miles from the Stellafane convention in Vermont, has a love of a pitch-black sky, and she knows her way around the stars. Wendee Levy

Although Joan didn't know it, that night on a deserted road was the start of something great for the woman who later became my sister-in-law. On August 11, 1999, Joan, her sister Wendee (my wife), and other family members joined me on the Regal Empress cruise ship to catch a 50-second sunrise total solar eclipse. Joan must have enjoyed the experience: A year later, when we attended a neighborhood production in which she was a cast member, we read on the program notes that she "wants to see a second solar eclipse." That dream came true, for she and her sister Gail joined us on a cruise on the Aegean Sea for the March 29, 2006, eclipse. Although a passion for eclipses is only a small part of a larger enthusiasm for the sky, I suspect that Wendee's sisters aren't done with eclipse chasing.

This excitement extends to other special events in the night sky, as well. On the evening of November 18, 2001, Joan took Wendee's advice and went outdoors to see if any Leonid meteors were crossing the frigid night. "I'll just stay out a few minutes and see if I see one," she said. After those few minutes, she went inside to fetch her husband. The catch was well worth it over Long Island where Joan viewed the shower, but Wendee and I observed from a dry lake bed in Alice Springs, Australia, and got something even better: In a few entrancing hours, we counted more than 2,400 meteors.

Each streak across the sky is fast, almost instantaneous, and then it's gone. But like most events in the night sky, it leaves a memory that never dissipates. Just observing a dark sky is a memory that Joan particularly treasures, enough that whenever she sees a dark sky with — as my grandmother might say — stars hanging like baseballs, she calls it "a David Levy Sky."

The sky is magical, and each of us can find our own magic by looking to the stars on a clear night.

NASA balloons funded Future Mars landers may deploy small balloons to sample the air and shoot video. NASA announced contracts launching the project February 17.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

NASA/ESA/K. Cook (Lawrence Livermore National Laboratory, USA)

Weak arms. Astronomers using the Hubble Space Telescope imaged NGC 4921, a spiral galaxy with little star formation in its arms.

Astronomers capture meager spiral

Hubble Space Telescope scientists released this view of an anemic spiral galaxy February 5. The galaxy, NGC 4921, is a rare spiral among many elliptical galaxies in the Coma Galaxy Cluster. The Coma Cluster contains more than 1,000 galaxies and is some 320 million light-years distant.

Rich concentrations of galaxies like the Coma Cluster have many interactions and mergers. Through these events, most spirals become ellipticals. NGC 4921, however, has remained a spiral. It's also an odd one. Spiral galaxies typically have active star formation occurring in their arms, which makes the arms appear bright. NGC 4921 has much less star formation, and so its spiral arms are dimmer and smoother than the arms of most spirals. Interestingly, the galaxy is the brightest spiral in the cluster.

Hubble's sharp eye also imaged thousands more remote galaxies around, and even through, NGC 4921. Kem Cook of the Lawrence Livermore National Laboratory in California led the group who captured the 80 exposures — in both near-infrared and yellow light — combined to produce this image. **— LIZ KRUESI**

18 Astronomers discover planet just twice Earth's diameter

20 NASA revs up new lunar rover

21 Pluto's full atmosphere revealed

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Taking a closer look at asteroids

Apollo sample pinpoints lunar crust's age

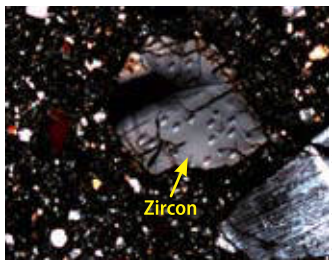
A small sliver of the mineral zircon offers the most accurate estimate to date of when the Moon's outer crust became solid. Scientists reported the finding February 1 in *Nature Geoscience*.

In the standard theory, a Mars-sized body slammed into Earth about 4.5 billion years ago. The debris coalesced into a spherical body, but the Moon's surface remained molten for some time. Earth's new satellite gradually cooled, forming a crust. But when?

A sample of Moon rock that Apollo 17 astronauts brought home in 1972 offers new information. Researchers headed by Alexander Nemchin at Curtin University of Technology in Bentley, Australia, dated a broken crystal of zircon in the Apollo rock.

Uranium isotopes in the zircon decay at a predictable rate, forming lead. By measuring the proportion of uranium to lead in the zircon, Nemchin estimated how many years have elapsed since the zircon crystallized in cooling magma. The fragment, about 0.5 millimeters wide, turned out to be 4.417 billion years old — plus or minus 6 million years.

Based on the zircon's age, the researchers estimate that most of the Moon's crust was solid within 100 million years after its violent birth. Some areas of the Moon may have remained molten for a few hundred million years afterward. **— DANIEL PENDICK**



Alexander Nemchin

Crystal clock. This tiny chip of zircon formed 4.417 billion years ago, relatively soon after a Mars-sized impactor slammed into Earth and created the Moon.

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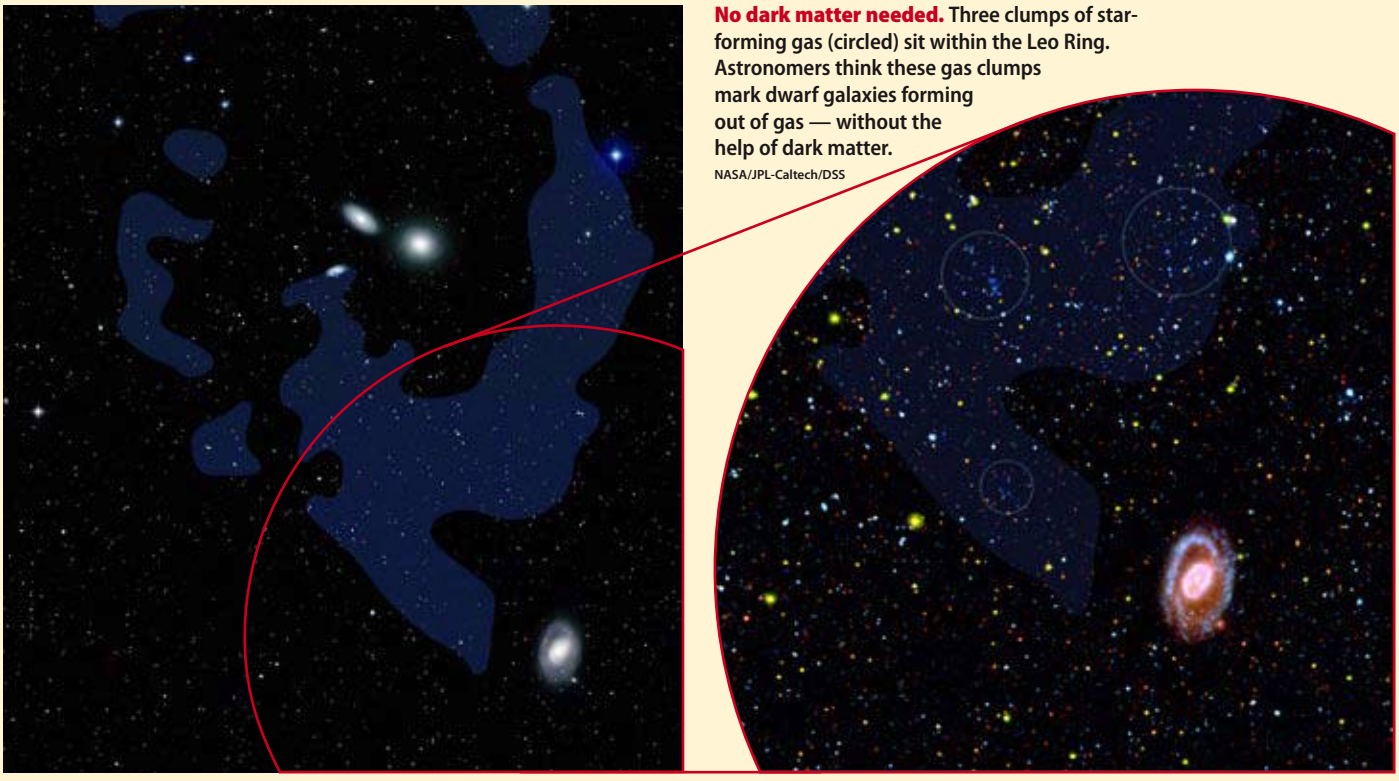
Swift kick A study in the January 27 *Physical Review Letters* says that black-hole mergers can cause one of the pair to fly off at speeds up to 22 million mph (35 million km/h).



No dark matter needed. Three clumps of star-forming gas (circled) sit within the Leo Ring. Astronomers think these gas clumps mark dwarf galaxies forming out of gas — without the help of dark matter. NASA/JPL-Caltech/DSS

Galaxies may have formed from primordial gas alone

When most galaxies form, dark matter — invisible matter that astronomers detect only by its gravitational pull — acts as scaffolding to which luminous matter bonds. However, astronomers may have found evidence that galaxies can form from primordial gas alone — no dark matter needed. The scientists, led by David Thilker of Johns Hopkins University in Baltimore, published their study February 19 in *Nature*.

The astronomers viewed the Leo Ring, a huge stream of hydrogen and helium surrounding massive galaxies M105 and NGC 3384, with NASA's Galaxy Evolution Explorer (GALEX). For 25 years scientists have observed the Leo Ring in only visible and radio wavelengths. They had found that the ring has little, if any, dark matter.

GALEX observed the ring in ultraviolet light. It spotted ultraviolet emissions showing several clumps of recent star formation. These star-forming regions indicate dwarf galaxies are likely growing within the ring.

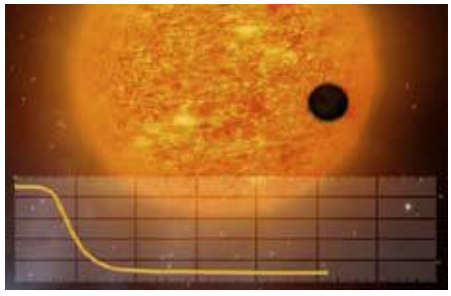
The possible dwarf galaxies also seem deficient in "metals" — elements heavier than helium. As the universe aged, massive stars forged metals. The Leo Ring might be pristine gas from the early universe, which means the gas has remained unaltered for some 13 billion years. So a low amount of metals and a lack of dark matter — both seen in these growing galaxies — imply that galaxies in the early universe may have formed in a different way than present-day galaxies. The team is planning follow-up observations to determine if the gas really lacks metals. **— L. K.**

Astronomers discover planet just twice Earth's diameter

Daniel Rouan of the Observatoire de Paris Lesia and colleagues used France's Convection Rotation and Planetary Transits (COROT) satellite to discover the smallest planet yet using the transit method. When a planet passes in front of (or "transits") its star, it blocks some of the star's light. Scientists can track this periodic dimming. The team announced its finding February 3 at a science conference about COROT.

The team first observed the planet, COROT-7b, about a year ago. While the scientists could directly determine from that observation COROT-7b's diameter — just twice that of Earth — they had to follow up with ground-based observations to determine its mass. Due to uncertainties that come from wobbles and other movements of the star's surface, the most precise value as of now is 5 to 11 Earth masses.

COROT-7b orbits its parent star in a little more than 20 hours, and it's only a few stellar radii away from the star. This "hot super-Earth" is likely either rocky or metallic. Future observations are needed to learn more about the planet's composition. **— L. K.**



Star block. One method astronomers use to locate extrasolar planets is to look for a periodic dimming of starlight. Here, a planet is in front of its parent star, blocking some of its light. The COROT satellite has detected the smallest planet yet found with this method. Its diameter is only twice that of Earth. CNES

NEW SCIENCE CENTER
New England's first air and space science center opened March 6 in Concord, New Hampshire. The McAuliffe-Shepard Discovery Center offers interactive science exhibits, a planetarium, and educational programs.

STARDUST MEMORIES
February 7 marked the 10th anniversary of the launch of NASA's Stardust spacecraft. Its return capsule delivered the first comet samples to Earth in 2006.

A DOUBLE FOR HUBBLE
The public cast 139,944 votes to choose a target for the Hubble Space Telescope. The winner, with 50 percent of votes cast, is a pair of colliding spiral galaxies called Arp 274.

WILLKOMMEN TO THE ANTARCTIC
Germany officially opened the permanent Antarctic Neumayer Station III February 20. As many as 50 researchers and technicians will work at the base in summer.

WARNING: GRAPHIC SPACE SCENES
T-minus, a new graphic novel about the Space Race by writer Jim Ottaviani and artists Zander Cannon and Kevin Cannon, is slated for publication May 19.

MARS ON TAP
Radar probes by the Mars Reconnaissance Orbiter reveal that ice in north polar deposits is more than 99 percent pure water. Scientists reported the finding February 12 in *Geophysical Research Letters*.

NO EXPRESS STOPS
On February 4, the European Space Agency decided to extend operations of its Venus Express, Mars Express, and Cluster missions until December 31, 2009.

NAME THAT GAP
Astronomers formally assigned names to 9 gaps in Saturn's rings February 9: Bond, Dawes, Herschel, Russell, Jeffreys, Kuiper, Laplace, Bessel, and Barnard.

NORTH KOREA'S NASA?
Rodong Sinmun, the North Korean Communist Party's official newspaper, said February 7 it was committed to pursuing a space program for "peaceful purposes."

CASSINI'S 100TH BLAST
The Cassini spacecraft at Saturn fired its engine for the 100th time January 23 to adjust its orbit for a planned flyby of Titan February 7.

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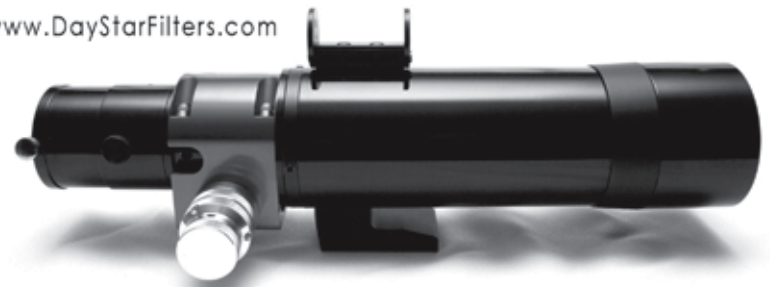

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Black holes dance. Astronomers found the closest pair of black holes yet. Other pairs have been discovered in the past, but those black holes were much farther apart. These are less than one-third of a light-year away from each other. P. Marenfeld/NOAO

Astronomers identify black hole twins

Astronomers have found a likely close binary supermassive black hole system where less than one-third of a light-year separates the two black holes. (The distance between the Sun and the next nearest star is about 13 times that value.) Todd Boroson and Tod Lauer, both of the National Optical Astronomy Observatory, made the find after rummaging through the Sloan Digital Sky Survey (SDSS) catalog of about 17,500 quasars (bright centers of active galaxies). They published their results March 5 in *Nature*.

Material falling into a black hole emits a distinctive light signature. Two black holes near each other would orbit one another and emit a dual light signature. Boroson and Lauer spotted the characteristic dual black hole signature in one object among the 17,500 quasars: quasar SDSS J153636.22+044127.0. Using the dual light signature, they determined that the black holes are almost certainly at the same distance from us. Boroson and Lauer also calculated the masses of the two black holes — one is some 20 million times the Sun's mass, the other about 800 million times.

They think the two black holes complete a full orbit around each other in about 100 years. This means that by studying SDSS J153636.22+044127.0 in a few years, astronomers should verify the black holes' orbital motions. If they are indeed orbiting each other, this provides evidence that as massive galaxies collide, their supermassive central black holes orbit each other and eventually merge. **— L. K.**

NASA

New Moon buggy. The prototype Lunar Electric Rover (LER) can travel hundreds of miles on a single charge and can protect astronauts from solar storms. Inset: The LER's "suitport" system allows astronauts to step directly in and out of their suits, which eliminates the need for a full-sized airlock.

NASA revs up new lunar rover

The Apollo Moon rover looks like a homemade dune buggy compared to the new Lunar Electric Rover (LER) that cruised the U.S. capital during President Obama's inaugural parade January 20. The LER solves a major problem for future lunar missions: How can astronauts explore lots of terrain while remaining safe from exposure to hazards such as solar radiation storms?

NASA astronaut and engineer Michael Gernhardt led the team that developed the LER at Johnson Space Center in Houston. The first-generation rover had no cabin, leaving astronauts vulnerable if a solar storm buffeted the lunar surface. It also limited the exploration range to the amount of time that an astronaut could spend in a space suit.

Prolonged exposure to energetic particles from the Sun (solar protons) could potentially be fatal. Astronauts would have to quickly return to base to huddle in a shielded room until the protons ceased.

Alternatively, Gernhardt's team thought, they could just bring their radiation shelter with them. So the roof of the LER contains water, which absorbs solar protons.

Next challenge: getting into the cabin fast enough to escape radiation exposure. Gernhardt knows a lot about getting in and out of pressurized environments. On July 20, 2001, he was the first astronaut to spacewalk from the International Space Station.

It took around 6 hours to get outside, much of it waiting in an airlock. On the Moon, entering a rover through an airlock would require too much time to get back inside and wait out a solar storm. It would also allow astronauts to track abrasive lunar dust into the cabin.

So the LER team developed a new "suitport" system. The LER's two space suits attach to a hatch at the rear of the cabin. To get in, an astronaut opens an inner door, swings the suit's backpack gear aside, and steps in. Pulling two levers seals the suit, venting only one-quarter of a cubic foot of air.

Getting back into the rover from the lunar surface quickly would be critical during a solar storm. Gernhardt says it would take about 20 minutes for an astronaut to connect to the suitport, seal it, and climb into the safety of the LER.

By roving in a convoy of two LERs and carrying solar panels to charge batteries, astronauts could range some 375 miles (600 kilometers) from base, Gernhardt estimates. The convoy approach provides a backup: If one vehicle breaks down, the crew can return to base in the other.

The LER offers a major improvement in mobility, comfort, and safety for future lunar explorers, Gernhardt says. (He hopes the lunar missions get underway in time for him to have a shot at one.) In a single work day, astronauts could cover lots of terrain and make several trips outside for up to an hour each. "Then I sleep in it that night and get up the next day and keep going," he says. "It just tremendously expands the exploration range that you are able to achieve." **— D. P.**

Pluto's full atmosphere revealed

Not like home. Pluto may contain methane patches on its surface, as shown in this artist's impression. Charon appears above and left of the limb. ESO/L. Calçada

Using a precise spectrograph (a tool that breaks down an object's light into its component colors, or wavelengths), astronomers have directly studied Pluto's lower atmosphere. They determined that its atmosphere is about –290 °F (–180 °C) on average, some 70 °F (40 °C) warmer than its surface, which is –364 °F (–220 °C). By studying Pluto's light spectrum, they also found unexpectedly large amounts of methane in its atmosphere. The astronomers, led by Emmanuel Lellouch of the Observatoire de Paris, will publish their findings in an upcoming issue of *Astronomy & Astrophysics Letters*.

For some 20 years, astronomers have studied Pluto's thin upper atmosphere by observing the dwarf planet as it blocked light from a background star — a technique called "stellar occultation." Yet the lower atmosphere remained a mystery. The Cryogenic Infrared Echelle Spectrograph (CRIRES) attached to ESO's Very Large Telescope (VLT), finally shed light on Pluto's lower atmosphere. "The combination of CRIRES and the VLT is almost like having an advanced atmospheric research satellite orbiting Pluto," says co-author Hans-Ulrich Käufl.

The astronomers offer two models that could explain Pluto's atmosphere. One is that a thin layer of methane covers the dwarf planet's surface. The other model says that methane patches exist on the surface. NASA's New Horizons mission, launched in 2006, will also provide more information about the atmosphere after it reaches Pluto in 2015. **— L. K.**

Fermi spots most powerful GRB ever

As a massive star in the constellation Carina collapsed to form a black hole, it released a powerful gamma-ray burst (GRB) — and NASA's Fermi Gamma-ray Space Telescope was there to see it. Dubbed GRB 080916C, the event set records for the highest peak energy and the greatest total energy released. Fermi scientists reported the discovery online February 19 in *Science Express*.

The GRB occurred 12.2 billion light-years from Earth. Given GRB 080916C's extreme distance and peak energy, its total radiated energy — if released uniformly in all directions — was equivalent to some 9,000 supernovae.

During a GRB, the collapsing star emits opposing jets of material at near light-speed along with focused beams of gamma rays and other radiation. The peak energy of the gamma rays from GRB 080916C indicates that its jets moved at better than 99.9999 percent of light-speed — the fastest ever recorded.

The GRB left astronomers with an unsolved mystery. Fermi detected the first wave of high-energy gamma rays 5 seconds after the initial low-energy emission. This could be because the gamma rays were produced at different times or by different processes.

But new theories of gravity predict that higher-energy gamma rays travel slightly slower than their low-energy counterparts. Over a distance of 12.2 billion light-years, the effect could become measurable. If this is what happened in the case of GRB 080916C, it would be the first time scientists have observed the effect. **— D. P.**

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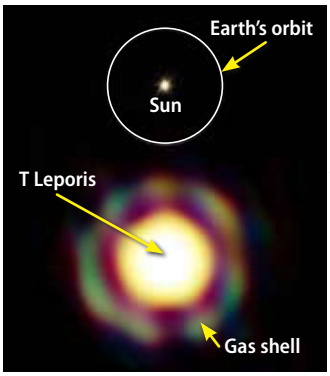
Dune moon A report in the February 11 *Geophysical Research Letters* estimates that dunes may cover one-fifth of Titan, Saturn's largest moon.



ESO/Jean-Baptiste Le Bouquin et al.

Signs of aging. In this false-color image taken in near-infrared light, a shell of dust and gas surrounds the star T Leporis.

T Leporis shows its face

In a technical triumph, a team of French astronomers has created a color image showing the disk of the red-giant star T Leporis surrounded by an extended shell of gas. The astronomers used three European Southern Observatory (ESO) telescopes in tandem to create the super-sharp photo, which ESO released February 18. A scientific report on the project is slated for publication in *Astronomy & Astrophysics*.

T Leporis is about 100 times wider than the Sun. As the aging star runs out of nuclear fuel, it expels about 1 Earth mass of gas and dust per year. This material forms a shell around the star.

Astronomers imaged T Leporis and its shell by combining observations from three different 1.8-meter telescopes at ESO's Paranal Observatory in Chile — a technique called interferometry. Combining light from the scopes created a new instrument, the Very Large Telescope Interferometer (VLTI). Its photo sharpness is equivalent to that of a telescope 330 feet (100m) across.

The VLTI studied T Leporis over several nights, gathering the star's near-infrared emission. The image is the first photo of a stellar disk rendered in false color by observing the same star in different wavelength ranges. **— D. P.**

Sky survey finds dusty universe

Using the third data release of the Sloan Digital Sky Survey (SDSS), astronomers have determined that the universe is dustier than previously thought. The team studied 85,000 quasars (the bright centers of active galaxies) behind intervening galaxies and found the foreground galaxies' dust reddens the quasars' light. The team, led by Brice Menard of the Canadian Institute for Theoretical Astrophysics, submitted its study to the *Monthly Notices of the Royal Astronomical Society*.

This reddening occurs because dust grains scatter blue light and let red light through — in the same way Earth's atmosphere reddens a sunset. In fact, galaxies probably have about as much dust in their outer regions as they do in their disks.

This finding is important because astronomers use the brightness of certain stellar explosions — called type Ia supernovae — to study the universe's expansion. Using these supernovae, astronomers have found that the expansion is actually speeding up — and they blame it on a mysterious cosmic component called "dark energy." A dustier universe could redden a supernova's light on its path to Earth. However, Menard explained that this dust doesn't get rid of the need for dark energy to explain current supernova data. **— L. K.**

BRIEFCASE

Wrong place, wrong time

On February 10, two communication satellites collided in orbit. One was owned by a U.S. communications company, the other by Russia. The collision, the largest ever between two man-made space objects, occurred about 490 miles (790 km) above Siberia. Some 600 pieces of space junk were scattered in the process. — L. K.

Asteroid buzzes Earth

A space rock between 70 and 160 feet across (21 and 49 meters) whizzed by Earth March 2 at 8:44 A.M. EST. At closest approach, it was some 40,000 miles (64,000 km) away — that's about one-fifth the Earth-Moon distance. Astronomers at the Siding Spring Observatory in Australia discovered the asteroid February 28 and determined then that it didn't pose a threat to Earth. — L. K.

The Zoo needs you

The Galaxy Zoo project launched its second phase February 17 at www.galaxyzoo.org. In the first phase of Galaxy Zoo, project scientists chose 1 million galaxy images from the SDSS database and asked the public to decide whether a galaxy was spiral or elliptical and which way it was rotating. The new Galaxy Zoo asks the public to look in more detail at 250,000 of the brightest galaxies and spot strange and unusual characteristics. — D. P.

25 years ago in *Astronomy*

June 1984

The editors of *Astronomy* wrote about the possible NASA space station in "Space Stations: The High Frontier" in the June 1984 issue. What eventually became the International Space Station (ISS) began, like all space missions, as an idea.

From the get-go, NASA anticipated the ISS' many possible projects. As the editors wrote, the agency "knows that new uses will surface once the station is operational and flexibility is essential to keep the station from quickly becoming obsolete."

The ISS was supposed to launch in the early 1990s, but setbacks changed the date to 1998. That was when in-space assembly first began. Construction continues today on the ISS as astronomers also conduct scientific research.

June 1999

10 years ago in *Astronomy*

In the June 1999 issue of *Astronomy*, Sharon Begley wrote about the rising tide of data from large surveys. Begley discussed how astronomers hoped to manage that information in "Cosmic Flood."

Data from early NASA missions amounted to 10 trillion bytes from about 1,000 experiments on some 400 missions over several decades. Astronomers could keep up with those amounts. Today, the Sloan Digital Sky Survey has produced 70 trillion bytes of data over 8 years. And the upcoming Large Synoptic Survey Telescope will produce about 20 trillion bytes a night.

Luckily, astronomers have found ways to manage at least a portion of the data. They've created data mining programs that correlate objects to make searching (and analyzing) easier. Computer analysis has improved dramatically since 1999, and a survey's computing power is now just as important as the telescope itself. **— L. K.**

Titan rainfall fills lakes

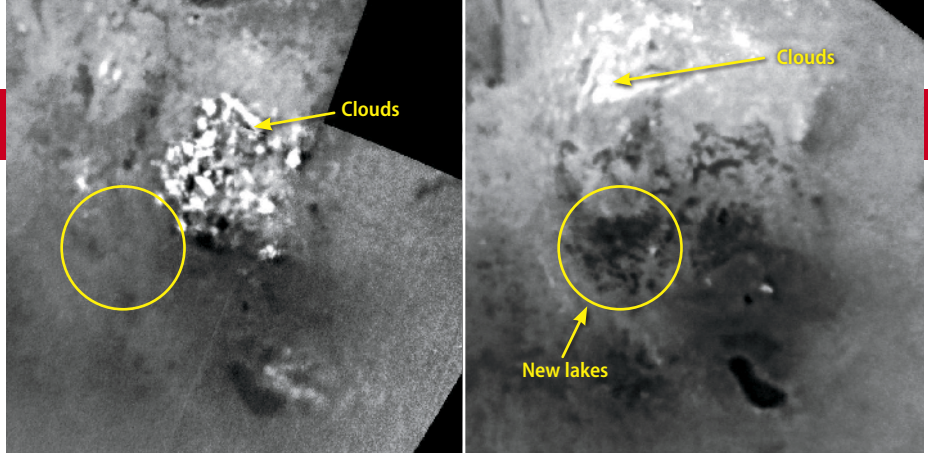
Before-and-after infrared images from NASA's Cassini orbiter show what may be the outcome of rain clouds filling the hydrocarbon lakes on Saturn's moon Titan. In an image from 2004, clouds hovered over a portion of Titan's southern "lake district." Then, in 2005, large dark patches — presumably methane lakes — appeared where none existed the year before.

The study backs the idea that some of Titan's methane seas rise and fall seasonally with changes in rainfall. Scientists reported their analysis of the Cassini images January 29 in *Geophysical Research Letters*.

Spring starts in Titan's northern hemisphere in August. "As northern spring progresses, we expect to see the same kind of large convective cloud systems appear that Cassini observed at Titan's south pole upon its arrival at Saturn," says Elizabeth P. Turtle, an associate member of the Cassini imaging team at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. "Exactly when they start to form is one of the things we're eager to find out."

Northern summer peaks in May 2017. If Cassini continues to function long enough, it may see new lakes appear in the north. (Some lakes seem to stay full all year.) Cassini researchers recently finished a near-global map of Titan, which establishes a baseline for future observations of lake expansion.

Some of the north polar lakes are exceptionally large. The whopper known as Kraken Mare covers some 154,440 square miles (400,000 square kilometers). If filled to the brim, it would be 5 times the size of North America's Lake Superior. — **D. P.**

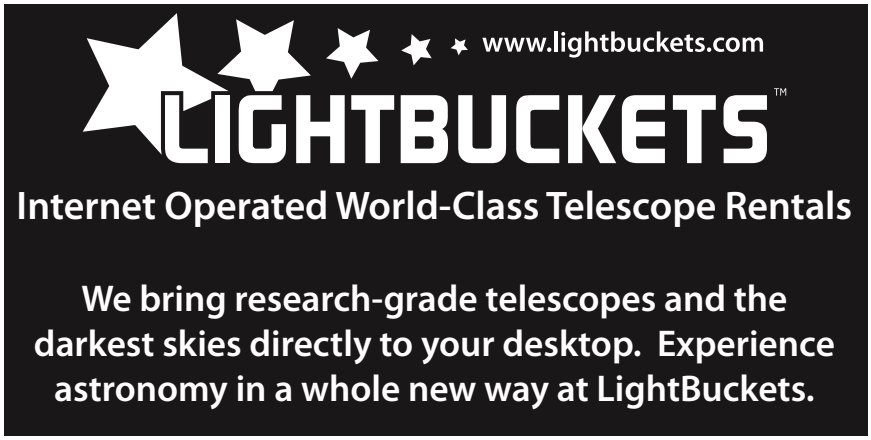


Stormy weather. Images of Titan's south polar region taken about a year apart appear to show methane rainstorms filling lakes. NASA/JPL/Space Science Institute

Taking a closer look at asteroids

Astronomers have a new way to measure distant asteroids. French and Italian researchers say that by combining the light from two telescopes they can probe asteroids as small as 9.3 miles (15 km) across at a distance of 124 million miles (200 million km) in the main asteroid belt.

This is like measuring the diameter of a tennis ball 1,000 miles (1,600 km) away. The researchers demonstrated the approach using two of the four 8.2-meter telescopes in the European Southern Observatory's Very Large Telescope at Chile's Paranal Observatory. — **D. P.**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Our universe may form one bubble of many in a vast multiverse. Cosmologists are now searching for signs of another bubble universe colliding with ours. **by Steve Nadis**

How we could see

How's this for a crazy idea? Imagine that our entire universe is actually a bubble, something like an oversized soap bubble. And what if our bubble happens to be just one of an infinite number of "bubble universes," some of which may be lurking nearby?

Unfortunately, there would be no way to see these other bubbles, communicate with them, or even verify their existence. Everything we see is restricted to a small chunk of our own bubble universe, a sphere some 13.7 billion light-years in radius called a "Hubble volume." That's all we can take in because — in our jurisdiction, at least — light has a strict speed limit that can never be broken.

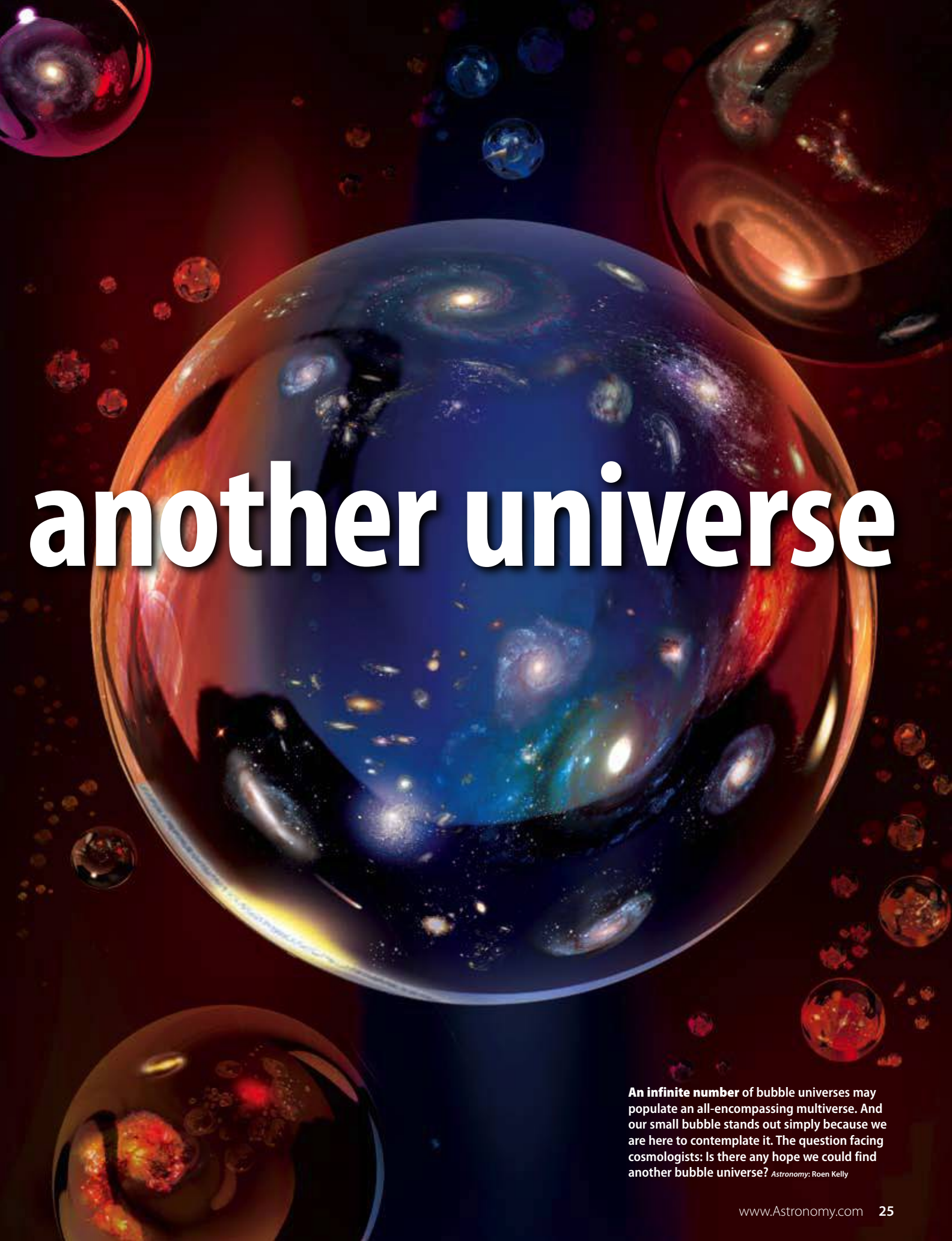
To a cosmologist interested in knowing the universe's structure, in all of its multivariegated glory, this would be incredibly frustrating. Yet an extenuating circumstance could lend some hope to inquisitive cosmologists (albeit with some risk as well). We could receive word from beyond our limited sphere if another bubble universe, moving at nearly the speed of light, smacked into us from out of the blue.

If that happened, things could get messy. One possible outcome: The energy released from the colliding bubble walls would simply wipe us out. It's possible, of course, that our corner of the cosmos would be far enough from the crash site to survive the blast. Yet we could still be obliterated if our universe underwent a sudden phase change, instantly switching over to the intruding bubble's "vacuum state." In all likelihood, it would have different physical properties and sit at a different energy level than our own. Such a process would vaporize everything in our world, including us. If this were to happen, there wouldn't be much time for reflection after the fact or for pondering the ins and outs of the various scenarios.

Let's suppose instead that we live far enough away and our bubble wall protects

Contributing Editor **Steve Nadis** *lives in Cambridge, Massachusetts. His most recent* Astronomy *article — "Do cosmic flashes reveal secrets of the infant universe?" — appeared in the June 2008 issue.*

another universe



An infinite number of bubble universes may populate an all-encompassing multiverse. And our small bubble stands out simply because we are here to contemplate it. The question facing cosmologists: Is there any hope we could find another bubble universe? *Astronomy:* Roen Kelly

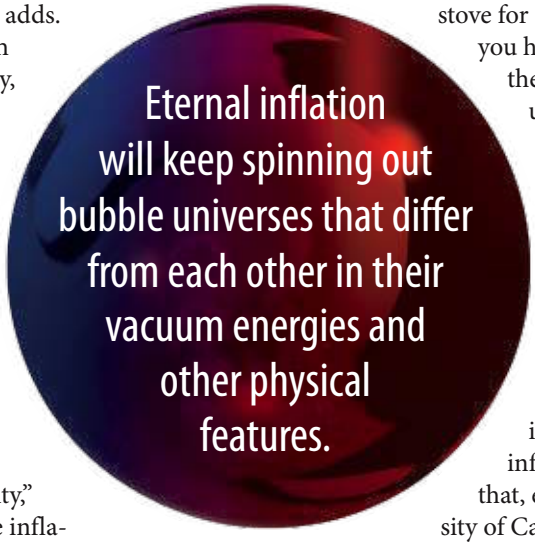
us sufficiently to survive the impact. And let's hope we're lucky enough not to get vaporized either. (The contents of the other bubble might not be so fortunate.) Would there be any way of knowing that such an event actually happened? Could we pore through the evidence, like investigators at a crash site, and figure out who hit what and when?

Inflating a bubble

Before we get to those questions, let's say a word about where these wild-sounding ideas come from. To a large extent, they all start with cosmic inflation — the concept that a brief but explosive growth spurt during the Big Bang resulted in the large, expanding, and relatively homogeneous universe we see today.

What does inflation have to do with bubble universes? Tufts University cosmologist Alexander Vilenkin, a pioneer of inflation theory, explains, "During inflation, you have some high-energy vacuum that drives the exponential expansion of the universe." But because inflation lasts just a tiny fraction of a second, this high-energy vacuum must decay to a lower-energy vacuum almost immediately. This happens when a bubble of lower-energy stuff forms amid the higher-energy stuff, just like a bubble forming in a pot of heated water. "We know this happens because we live in one of those [low-energy] bubbles," Vilenkin adds. The violent growth phase stops quickly, but the bubble retains enough oomph for continued expansion at a more leisurely pace.

Inflation as a whole isn't finished, however. Almost every version of the theory has the feature of "eternality," meaning that once inflation starts, it never really ends. It will stop in one region, only to start again somewhere else. That's possible because the vacuum material driving inflation has the strange property that it decays — by forming bubbles of lower energy — more slowly than it expands.


Eternal inflation will keep spinning out bubble universes that differ from each other in their vacuum energies and other physical features.

As long as the expansion rate exceeds the bubble formation rate, the process never ends. Eternal inflation will keep spinning out bubble universes that differ from each other in their vacuum energies and other physical features.

Let's return to our pot on the stove for a minute. When you heat the water to the boiling point, it undergoes a phase change and little steam bubbles form. As more and more bubbles form, they come together, and before long there's no water left — it's all air. Eternal inflation works like that, explains University of California at Berkeley physicist Ben Freivogel. Except in this case, he says, "The 'water' keeps expanding so that even as it's forming bubbles, it's never destroyed. And that's why inflation persists."

MIT physicist Alan Guth hit upon the idea of inflation in 1979 when he was a

postdoctoral student at Stanford. It has held up well to experimental scrutiny ever since. In fact, many cosmologists regard inflation as one of the most successful — if not *the* most successful — ideas in cosmology in decades. But even Guth admits that inflation is not a full-fledged physical theory because the mechanism behind the cosmic expansion remains unexplained. It will take a theory of "quantum gravity," which combines quantum mechanics and general relativity, to fully account for inflation.

Quantum gravity and strings

While there's no universally accepted or experimentally verified theory of quantum gravity at the moment, most physicists consider string theory the leading candidate. "Although inflation is more or less independent of string theory, there is the question of what makes inflation happen," says Anthony Aguirre, a physicist and cosmologist at the University of California at Santa Cruz. "None of the fields of the standard model [the current bible of particle physics] is capable of driving inflation, but string theory offers one possibility."

Moreover, string theory offers a picture that ties in well with the notion of eternal inflation and a cosmos composed of innumerable bubble universes. To visualize these ideas, some researchers invoke a concept called the "string theory landscape." The basic idea of the landscape is that the equations of string theory have a large number of possible solutions, each of which represents a possible universe with a different vacuum energy and different physics.

Consider all these solutions, or "vacua," as little dips or valleys sitting at different elevations on a hilly landscape. These vacuum states are not entirely stable, however, and can decay to a lower spot on the landscape. This happens when one bubble forms inside another. The energy difference between the two vacua then drives the new bubble's expansion. This is the basic picture of eternal inflation as well, so the two ideas fit together nicely.

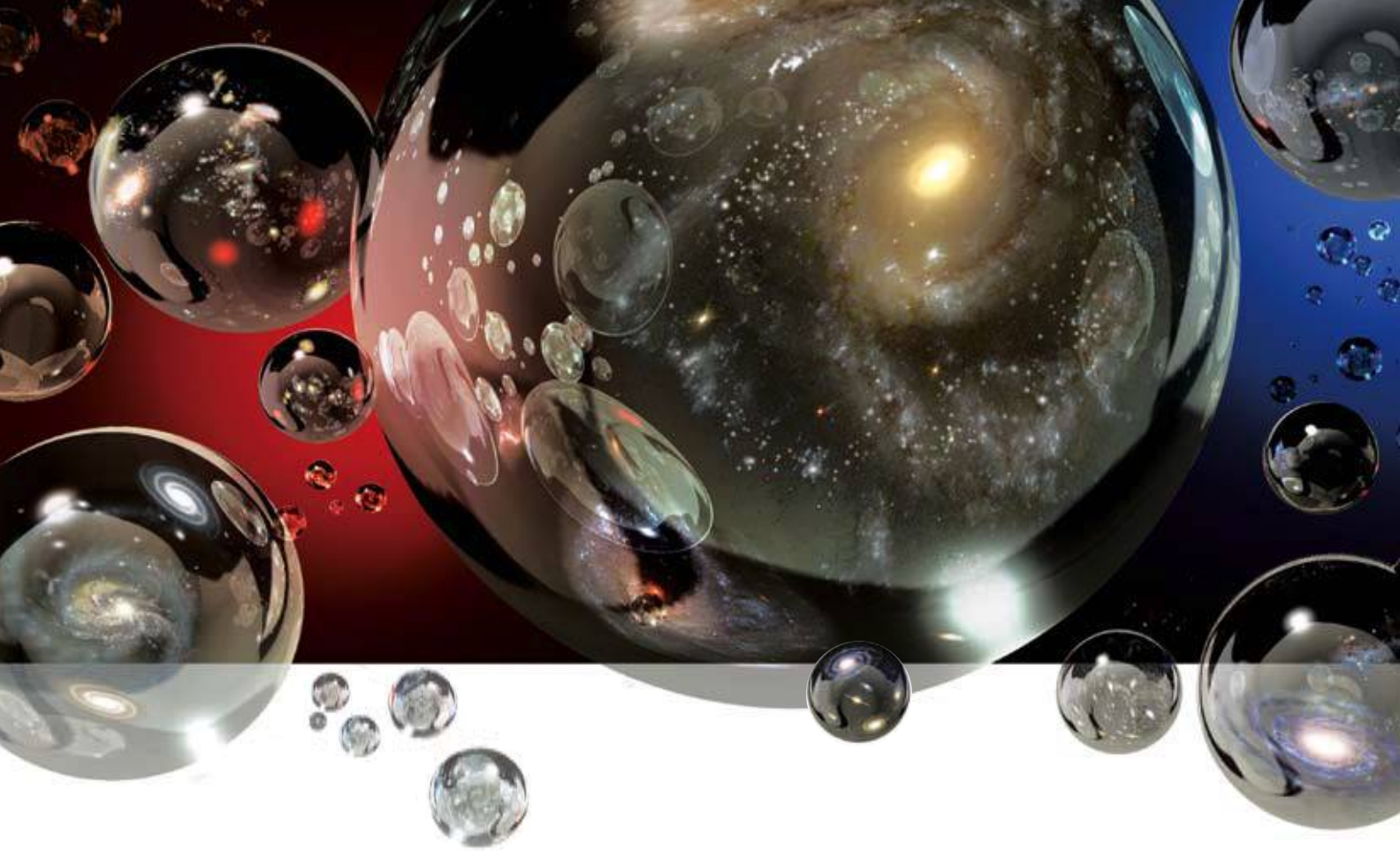
"If the landscape picture is right, we live in a bubble and there are other bubbles," explains New York University physicist Matthew Kleban. "If the landscape is right, then bubbles and string theory go hand in hand."

The landscape idea is extremely speculative, however. After all, the theory that spawned it — string theory — isn't close to being confirmed itself. Institute for Advanced Study physicist Nima Arkani-Hamed has called the debate over the landscape, eternal inflation, and multiple universes "one of the central controversies of our time."

When bubble meets bubble

Given this backdrop, it would be a tremendous coup for experimental physicists, theoretical physicists, and cosmologists to find evidence that supports these ideas. Kleban thinks bubbles may be our best shot. Obtaining firm evidence that another bubble crashed into ours would tell us that we live in a bubble and there's at least one other out there. It also would suggest a lot more bubbles exist that haven't hit us yet. "That wouldn't prove that string theory is correct," Kleban says, "but it would tell us that something strange and unexpected happened that's also something that string theory predicts."

The cosmic microwave background (CMB) offers the best place to look for clues. The signature would be an anomalous feature that other means cannot



explain. Emitted a few hundred thousand years after the Big Bang, the CMB is remarkably smooth, remaining uniform to one part in 100,000. A violent collision with another bubble, however, would deposit a huge amount of energy in one portion of the universe, producing a localized deviation from homogeneity. Such a crash would impose a direction on our universe — an arrow that points straight toward the center of the other bubble just before it slammed into us. That could show up in the CMB as an "anisotropy" that's not the result of mere random fluctuations.

This is just the sort of calling card that cosmologists look for. They already have uncovered one apparent anisotropy, called "the axis of evil," in the CMB data. Researchers have found that instead of being randomly distributed, CMB hot spots and cold spots appear to be aligned along a particular axis. If this proves to be a significant effect, it would suggest the universe has a specific orientation. And that would clash with hallowed cosmological principles avowing that all directions are equivalent; none are special or preferred. Many observers remain skeptical of this putative axis, claiming it may be a statistical fluke.

The definitive signature of a collision would be a circular feature centered around the preferred direction. "The effect would be limited to a disk," Kleban explains. "It would be strongest at one spot in the sky and would decrease in strength as you moved away from that spot. At some point, you'd stop seeing the effect altogether."

What if the sky appeared symmetric around the center of the disk, with perhaps concentric rings of different temperature running around it? Aguirre says, "It would be difficult to come up with an interpretation other than some other bubble colliding with ours."

The pessimists weigh in

What are the odds of a crash occurring near enough that it would show up as a disk in the CMB? One problem, Aguirre notes, is that inflation works against you. We need inflation in the first place to produce the bubbles that might ram into ours and leave visible traces. But because inflation took a tiny patch of space and blew it up into our universe, when we look far back in time, he says, "We only get to see a small patch of the universe. So the chance of there being a bubble that nucleated nearby is small. There's a second way that inflation works against you: Even if there is a bubble crash, whatever perturbations it leaves will get stretched and totally smoothed over."

Owing to these and other factors, Aguirre's analysis with Matthew Johnson of the California Institute of Technology reached a pessimistic conclusion regarding the likelihood of success. "While it is conceivable that by chance … we are close enough to a collision region to observe its signatures," they wrote in a 2008 paper entitled *Surviving the Crash*, "the more probable scenario [is one] where tantalizing clues of all the interesting dynamics of eternal inflation are up there in some particular direction on the sky, but remain forever hidden from us like the tiniest of needles in the cosmic haystack."

Vilenkin, who studied this question with Guth and Jaume Garriga of the University of Barcelona, considers the prospects of detection uncertain at best. "As the bubble grows to infinite size, there will be an infinite number of potential observers that could see a collision and an infinite number that could not," he says. "Until we know how to compare infinities, which is a tricky business, I don't think we can give a well-defined answer

to the question of how likely it is to observe a bubble collision."

The optimist club

Freivogel and Kleban, on the other hand, find some grounds for hope. They conclude the probability comes down to a product involving three numbers. The first has to do with the rate at which bubbles form, or "nucleate." Take that number and multiply it by the ratio of the vacuum energy outside our bubble to the vacuum energy inside during inflation. If that product is greater than one, astronomers should be able to see at least one bubble now. (If we waited an infinite amount of time, we should be able to see an infinite number of collisions, but who's got time for that?)

> "The product could be large, it could be small, or it could be about one. The best reason for hope is that we can't conclude that it's hopeless."
> — Matthew Kleban

The basic problem, Freivogel acknowledges, is that cosmologists don't really know any of these numbers. Take the first term, the bubble nucleation rate. Theorists know that number ought to be smaller than one — probably much smaller than one. Otherwise all the water in the proverbial pot on the stove would boil off, leaving no water to sustain eternal inflation. But without eternal inflation, this whole bubble scenario goes right down the drain.

As for that ratio, there's good reason to believe the vacuum energy outside our bubble is close to the Planck scale, which is the highest energy scale in physics. But the energy that drove inflation can't be near the Planck scale because that would have generated gravitational waves we would have seen already. So this ratio could be a big number.

When you multiply this big number by the small number corresponding to bubble nucleation, what do you get? Unfortunately, says Kleban, "The product could be anything. It could be large, it could be small, or it could be about one. The best reason for hope is that we can't conclude that it's hopeless."

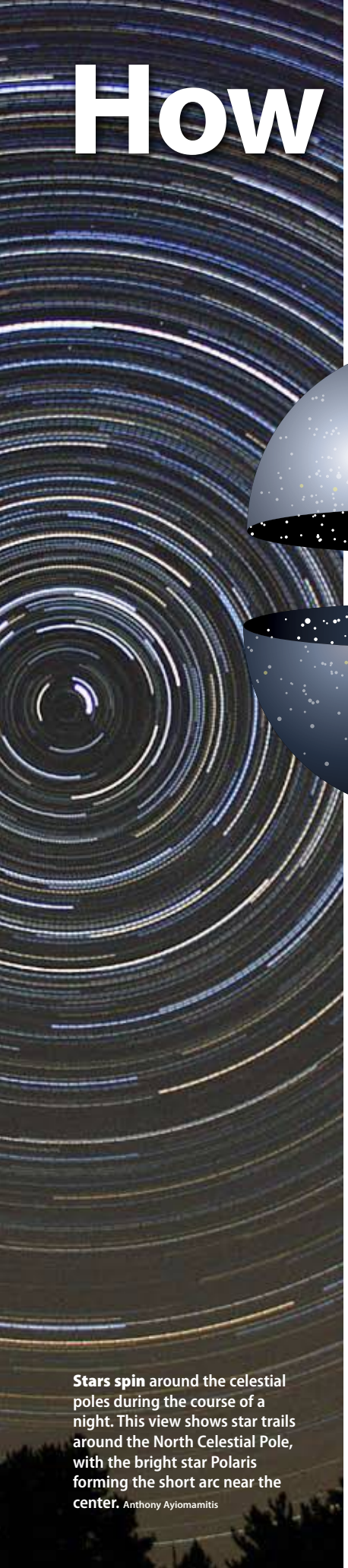
Though Freivogel is also optimistic, he doesn't think there's much chance for improving the calculation in the near term. Instead, he thinks theorists ought to focus more on observational signatures and the kind of measurements needed. Then all astronomers can do is go out and look, taking advantage of available CMB data, which gets better every year.

If we're lucky (assuming you're in favor of bubble collisions as a matter of policy), someday researchers might see the telltale disk. That would confirm the idea that we live in a bubble, which crashed into another bubble once upon a time. We'd then have learned about something more than just bubbles — namely that the thing we call the universe is a far more complex and interesting place than we ever imagined.

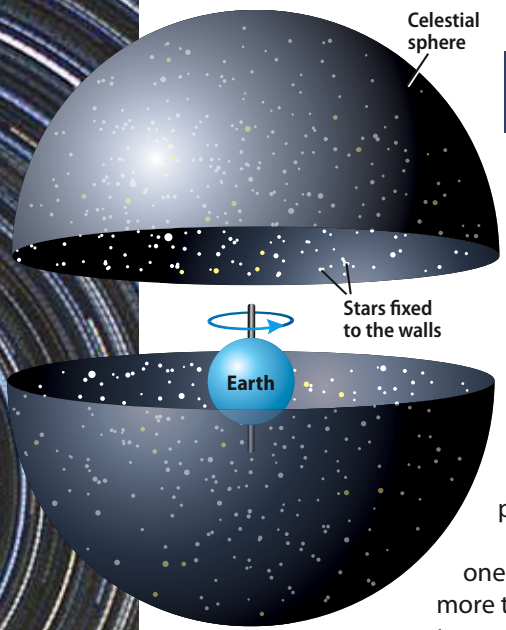
How we see the sky

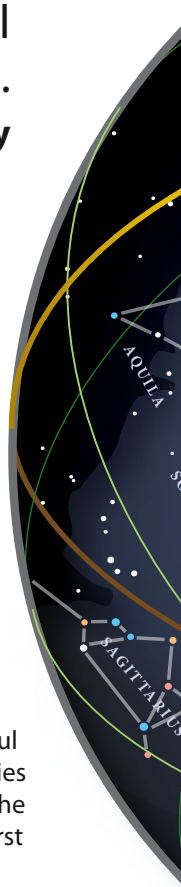
Astronomers use a concept called the celestial sphere to understand the sky and its motions.

by Richard Talcott; illustrations by Roen Kelly



Stars spin around the celestial poles during the course of a night. This view shows star trails around the North Celestial Pole, with the bright star Polaris forming the short arc near the center. Anthony Ayiomamitis





Head outside any clear night, and the star-studded sky seems like a vast dome above your head. It's as if all celestial objects lie on a giant sphere that rotates around us once each day. The Greek philosopher Aristotle (384–322 B.C.) developed a model of the universe based on this idea of a celestial sphere surrounding an immovable Earth.

Claudius Ptolemy, a second-century Greek astronomer living in Egypt, elaborated on the model. He added spheres for each wanderer — the Moon, Sun, and five known planets that constantly changed positions relative to the stars — inside the sphere of "fixed stars." Until the 17th century, many people believed those spheres were a physical reality.

The celestial sphere is a fiction, but it remains a useful one. The closest star beyond the Sun, Proxima Centauri, lies more than 250,000 times farther away. The movements of the stars pale in comparison with their distances, so to a good first approximation, the stars appear fixed.

The changes we see in the sky on any night reflect Earth's rotation on its axis. And the changes we see during the course of a year reflect Earth's orbital motion around the Sun. The concept of a celestial sphere makes both of these motions clear.

In these illustrations, we show a spherical Earth inside the celestial sphere. We have greatly exaggerated Earth's size to make its details obvious. The same holds true when we show Earth and the Sun together. At the scale of these illustrations, the entire solar system would be a mere point at the sphere's center.

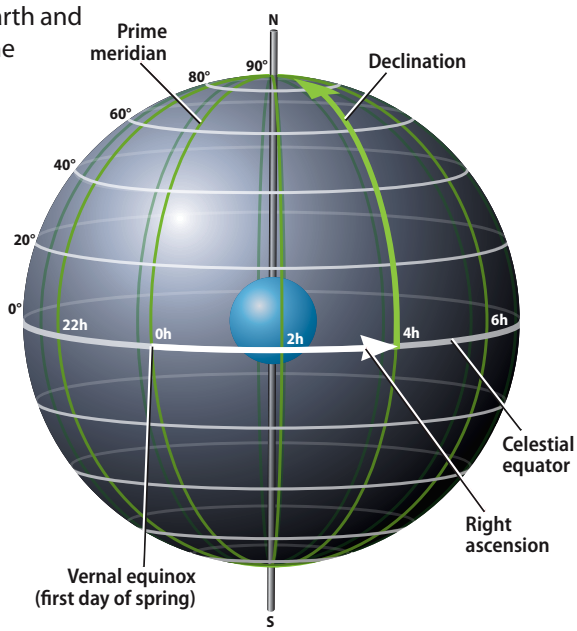
Star Dome

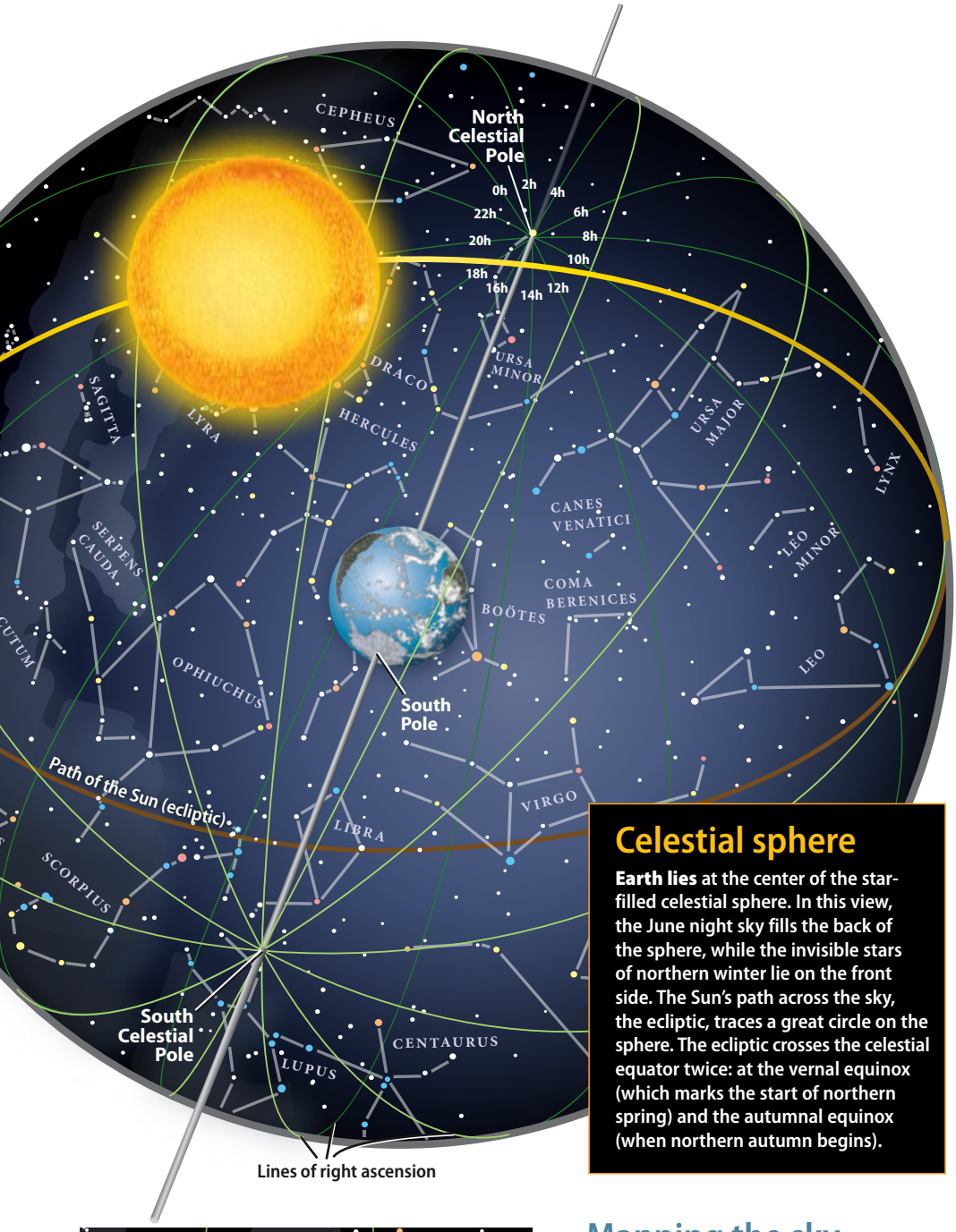
^ More than 2,000 years ago, scientists devised a model for the universe that envisioned all the stars placed on the skin of a vast sphere. In those days, people thought the sphere spun around Earth. Today, we know Earth spins under the celestial vault. At any given time on a clear night, an observer sees half of the full sphere.

Richard Talcott *is a senior editor of* Astronomy.

Celestial coordinates

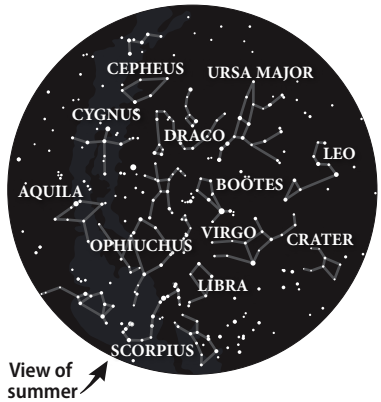
> To determine object positions, astronomers line the celestial sphere with a grid (in the same way geographers use latitude and longitude on Earth). Parallel lines of declination mark angles north and south of the celestial equator (equivalent to earthly latitude), while lines of right ascension mark angular distances east and west of a prime meridian (equivalent to earthly longitude). In the celestial case, the meridian runs through the position of the Sun on the vernal equinox.





Celestial sphere

Earth lies at the center of the star-filled celestial sphere. In this view, the June night sky fills the back of the sphere, while the invisible stars of northern winter lie on the front side. The Sun's path across the sky, the ecliptic, traces a great circle on the sphere. The ecliptic crosses the celestial equator twice: at the vernal equinox (which marks the start of northern spring) and the autumnal equinox (when northern autumn begins).

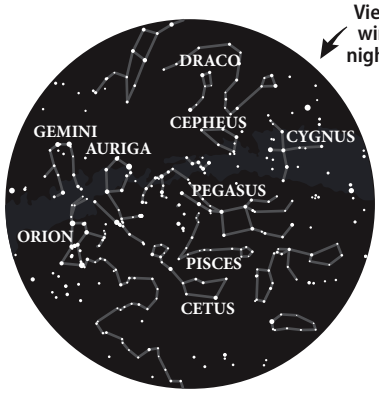


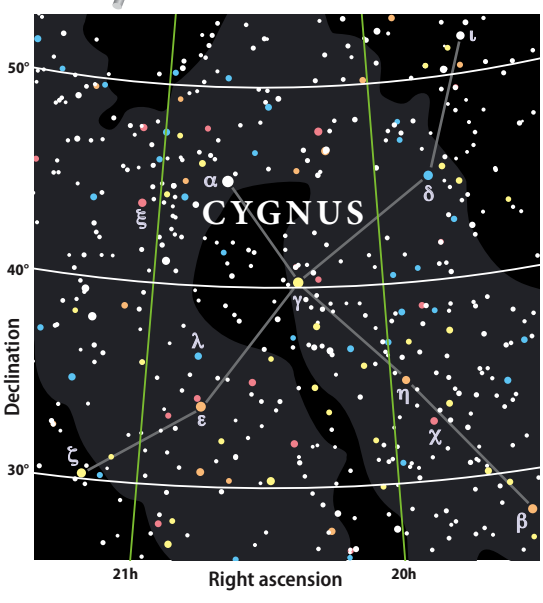
View of summer night sky

Reason for the seasons

As Earth revolves around the Sun, we see different seasonal skies. Although stars near the celestial poles don't move much throughout the year, stars closer to the celestial equator change dramatically. During northern winter, Earth's nightside displays Orion; in summer, the night sky features Scorpius. These patterns evolve slowly as Earth's axis precesses over a 26,000-year cycle.

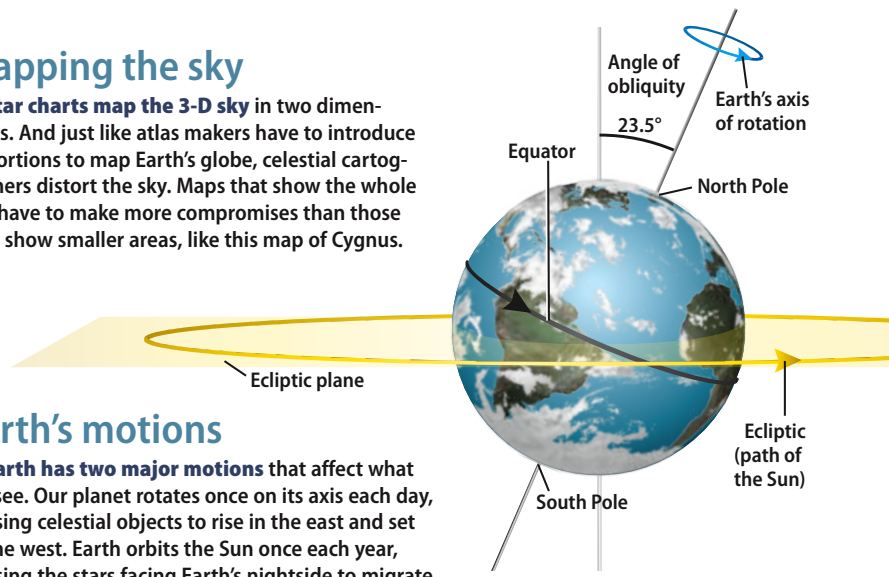
View of winter night sky





Mapping the sky

Star charts map the 3-D sky in two dimensions. And just like atlas makers have to introduce distortions to map Earth's globe, celestial cartographers distort the sky. Maps that show the whole sky have to make more compromises than those that show smaller areas, like this map of Cygnus.



Earth's motions

Earth has two major motions that affect what we see. Our planet rotates once on its axis each day, causing celestial objects to rise in the east and set in the west. Earth orbits the Sun once each year, causing the stars facing Earth's nightside to migrate slowly. This orbital path, called the ecliptic, tilts 23.5° to Earth's rotation axis.

Astronomy magazine

New science

Jet
A quasar — a type of active galaxy — spews jets of light and other radiation.
Intervening hydrogen gas
Light from a quasar's jet must pass through cool hydrogen clouds on its way to Earth. The gas cloud absorbs certain wavelengths characteristic to hydrogen.
Spectrograph
A spectrograph acts as a prism, splitting the jet's light into its spectrum of wavelengths.
Quasar's spectrum
Wavelengths characteristic to hydrogen show up on the spectrum as dark (absorption) lines. Scientists know exactly where these lines should be on a laboratory spectrum.
400
Wavelength (nanometers)
500
Astrocomb tick marks
Quasar's spectrum

Because the universe is expanding and objects are moving away from each other, a celestial object's lines shift to the red end of the spectrum.

By comparing the quasar's spectrum with the one from the laboratory, astronomers measure a redshift. From that redshift, they calculate how fast the object is receding. With the astrocomb's accuracy, scientists can observe this redshift year after year and chart precisely how it changes. After 20 years, they should be able to observe how much the universe's expansion is accelerating — or if it's actually slowing down.

In this image, the astrocomb frequencies (white lines) are superimposed on a simulated absorption spectrum from a quasar at redshift z=3.5 (when the universe was less than 2 billion years old). The astrocomb's spacing is exaggerated. *Astronomy*: Roen Kelly; simulated quasar spectrum: Michael Murphy

New technique closes in on dark energy

Astrocombing will revolutionize cosmologists' method of measuring cosmic expansion.

by Ashley Yeager

The universe's age is huge — hundreds of millions of times longer than a human lifetime. With our short lives, some people have the impression that the universe doesn't change much. The truth, says Harvard astronomer Abraham Loeb, is that everything is changing across the cosmos. However, it takes long time periods — even millions of years — for perceptible shifts in the fabric of space-time to occur.

Since no astronomer's career lasts millions of years, it makes understanding the history of the cosmos a bit like reading a book that's missing its middle chapters.

Advances of a new tool, however, promise to put the middle chapters back into our cosmic story. This device, called an astrocomb, acts like a precise ruler to calibrate the observations that existing tools, called spectrographs, make. Combining the two instruments pushes their technological limits and provides astronomers a chance to detect even the most minute cosmic changes — those that show the universe's expansion and the effects of a mysterious force called dark energy.

Ashley Yeager *is a freelancer who recently earned her masters in science writing from MIT.*

Seeing a shift

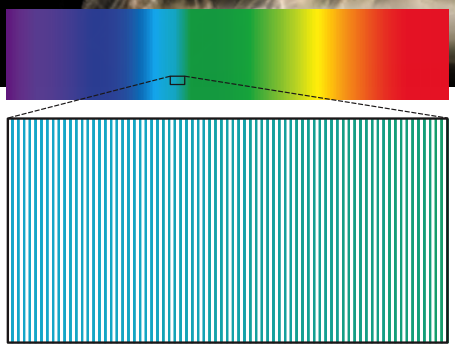
Slashing the cosmological wait time with the astrocomb would help astronomers catch a glimpse of the expanding universe — in real time. "It would be like watching a video rather than seeing a series of photos of the universe [as it expands]", says astronomer Sebastian Lopez of the University of Chile. The measurement wouldn't take millions of years, but rather 10 to 20.

> Understanding the history of the cosmos [is] a bit like **reading a story that's missing its middle chapters.**

Carnegie astronomer Allan Sandage in 1962 first suggested astronomers should be able to see the universe expand. Because space is spreading apart when astronomers study the light of a faraway galaxy, they should see that the light is stretched toward the red end of the spectrum, or redshifted, and also that this redshifted light changes over time. Sandage calculated the change would be so minuscule — equivalent to a shift near the size of molecules — that with the technology of the 1960s it would have taken at least 10 million years to detect.

To complicate matters, in the 1990s astronomers shocked the world with the discovery that the universe's expansion is accelerating. While studying bright stellar explosions called type Ia supernovae, scientists expected to find that the expansion slows down. But their observations revealed the opposite and led to the discovery of what later was termed dark energy — a sort of repulsive gravity force that's accelerating the universe's expansion. More than 10 years after its discovery, dark energy's nature still remains unknown, although not for a lack of effort. Cosmologists are working tirelessly to figure out what the stuff is and how it works. But that requires knowing exactly how fast the universe expanded in the past relative to how fast it expands today.

Unfortunately, all existing experiments that astronomers use to constrain dark energy's nature, and test and ultimately explain the universe's history, rely on



The astrocomb has millions of wavelengths spaced an equal distance apart. Scientists expect the comb to cover a range from the ultraviolet through the infrared. Theodor Hänsch

assumptions about cosmic geometry, Lopez says. Yet if we instead directly measured a small drift in redshift due to the expansion, that measurement wouldn't depend on any cosmological parameters or gravitational theories. The measurement, he says, would be a direct detection of the expansion.

This test would measure how the light from quasars billions of light-years from Earth stretches. Quasars are the active, and therefore bright, centers of galaxies. The unique test, now dubbed the Sandage-Loeb test after its creators, lets astronomers study cosmic epochs when the universe was 2 to 7 billion years old.

The European Extremely Large Telescope (E-ELT) is the largest telescope currently in the planning stages. If all goes well, the E-ELT will start science operations in 2018 and could observe how the universe is expanding by 2040. European Southern Observatory

Current dark-energy probes like supernovae and the Big Bang's relic radiation, the cosmic microwave background, can't provide useful information in this range.

Due to the lack of data in this part of the universe's story, astronomers are unsure how dark energy affects the expansion of the 2-to-7-billion-years region. Data from the Sandage-Loeb test would map the universe's expansion history from its early years to today and thus help theorists figure out what dark energy is, says cosmologist Dragan Huterer of the University of Michigan.

The experiment's success will ultimately "prove that everything is changing regarding the state of the universe far away," Loeb says. But probing quasars in these distant cosmic regions currently remains theoretical. Today's experimental cosmological tools, especially spectrographs, aren't yet precise or stable enough to make the measurement. The astrocomb promises to change that.

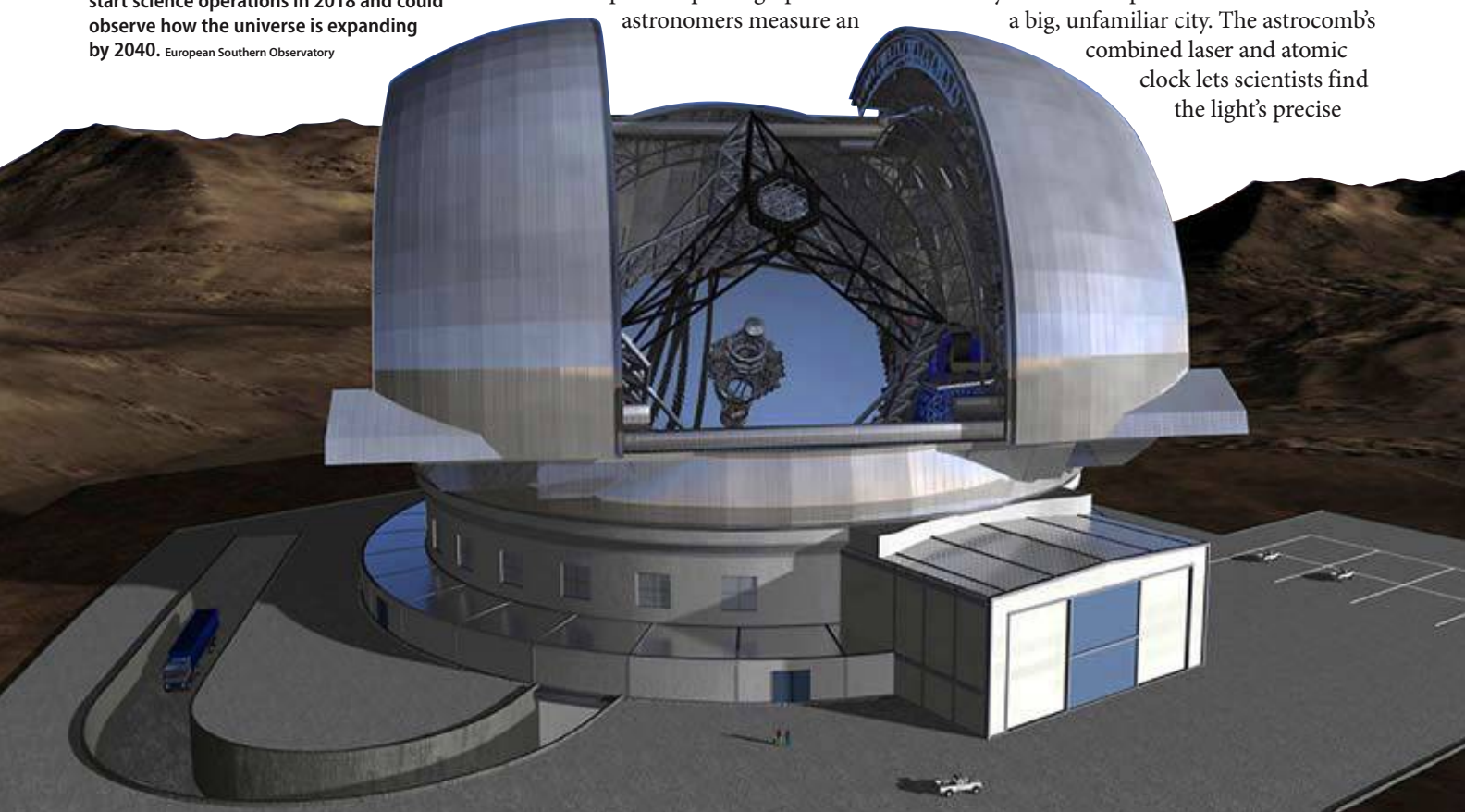
Ruling color

Astronomers use spectrographs to spread a celestial object's light into its component colors, or wavelengths, like a glass prism spreads sunlight into a rainbow. A more precise spectrograph will let astronomers measure an object's redshift more accurately. But to correctly measure wavelength, one must calibrate a spectrograph, just as a ruler has tick marks to precisely measure length. Making precise tick marks on a spectrograph, however, takes time.

Time is one of the quantities physicists can measure best, says Thomas Udem of the Max Planck Institute for Quantum Optics (MPQ) in Germany. That's because today's finest clocks — atomic clocks — lose or gain only one second after about a million years. To exploit this precision timepiece for physics and astronomy, Theodor Hänsch of the MPQ and John Hall of the University of Colorado at Boulder designed the "optical laser frequency comb," a tool that won the men half the 2005 Nobel Prize in Physics.

The tool transfers the clock's precision to a frequency comb — a special laser that emits short pulses of light in millions of extremely well-defined wavelengths only femtoseconds (or thousandths of a millionth-millionth of a second) long. The clock controls the laser's light and ensures an equal distance between each wavelength, just like the tick marks on a ruler or the teeth of a comb.

The astrocomb works similarly to the way a GPS lets a person find an address in a big, unfamiliar city. The astrocomb's combined laser and atomic clock lets scientists find the light's precise



position not in terms of X and Y coordinates, but in terms of wavelength. Then astronomers can measure much more precisely the spectral lines of astronomical sources. Just as people call the GPS the absolute calibrator of the space-time world, "we call the astrocomb the absolute calibrator of the wave world," says Harvard's Dimitar Sasselov. Astronomers know exactly where on the spectrum the wave is when it enters the telescope and how much it shifted from its original wavelength.

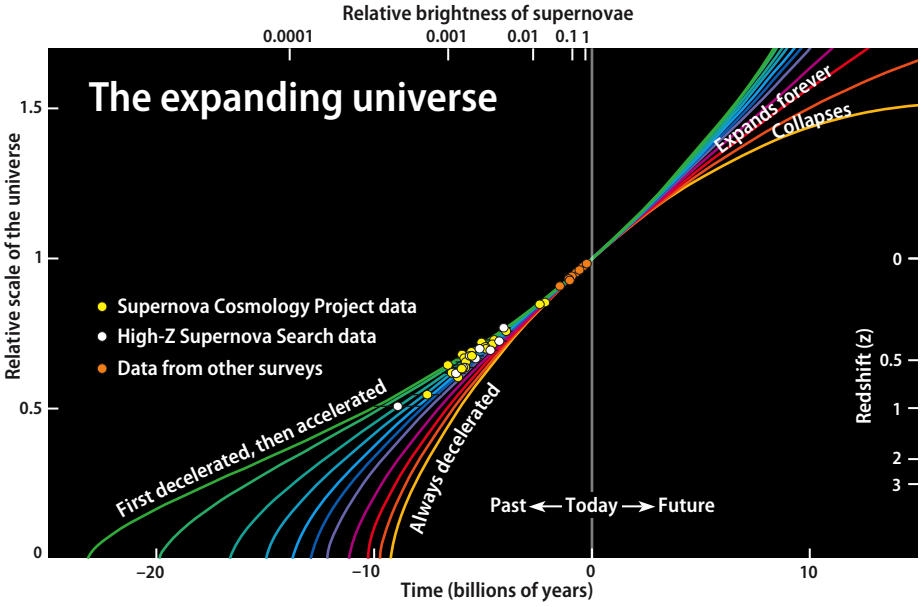
Real-time expansion

Exploiting the new calibration technique has become a serious research focus of Hänsch and others at MPQ and the European Southern Observatory (ESO). Their goal: measure cosmic expansion and begin to probe a region of space where we haven't yet explored dark energy.

Watching the universe expand in real time requires measuring a redshift drift

Their goal: measure cosmic expansion and begin to probe a region of space where we haven't yet explored dark energy.

of 1 centimeter per second. This corresponds to a measurement of a few tenths of a nanometer drift in spectrum light, says Michael Murphy, an astronomer at the Swinburne University of Technology in Australia. Making such a precise measurement demands not only an astrocomb's extreme calibration but also powerful telescopes and spectrographs not yet built. Using the future 42-meter European Extremely Large Telescope (E-ELT) — the largest telescope currently in the planning stages — and a spectrograph calibrated with more accurate "rulers" than exist today, astronomers could make such a measurement, he says. He adds that astronomers will also need to calibrate the spectrograph so they can measure spectra with accuracies of about one part in 30 billion, the equivalent to measuring Earth's circumference down to the millimeter.



Supernova surveys have pieced together the universe's expansion history. Future generations of the astrocomb — combined with the European Extremely Large Telescope and a next-generation spectrograph — have the potential of dramatically filling in the plot's bottom-left portion. By 2040 we could have a precise picture of a small part of the universe's history, and therefore of the universe's future. *Astronomy*: Roen Kelly, after Saul Perlmutter

In 2007, the Germany-based team built and tested a prototype astrocomb in the MPQ laboratory. They again tested it in March 2008 at the Vacuum Tower solar Telescope in the Canary Islands. They studied the Sun's spectrum in infrared light and measured shifts of 29.5 feet per second (9 m/s). With the test device, they saw better precision than today's standard tools can achieve, Udem says. In infrared light, current tools measure an accuracy of 32.8 f/s (10 m/s).

Another, better, prototype astrocomb and spectrograph is now in the works for use as early as this summer with the High Accuracy Radial velocity Planet Searcher (HARPS) instrument on ESO's 3.6-meter telescope at La Silla in Chile. The astrocomb must work accurately with HARPS before scientists consider building future generation astrocombs to use in conjunction with the E-ELT.

To continue advancing the potential of laser frequency combs, the German team has partnered with a company from MPQ called Menlo Systems GmbH. Hänsch and others founded the company to commercialize the calibration technique. These partnering efforts are to bring to reality the Cosmic Dynamics Experiment (CODEX), an ambitious spectrograph scientists will build for the E-ELT, and use it for the Sandage-Loeb test.

The E-ELT's foreseen first light is 2017, but funding constraints could delay construction. The second obstacle, says Jochen Liske of ESO, is whether CODEX becomes one of the first instruments astronomers put on the new telescope — a fate not yet decided.

Liske says that if all goes as planned — that the E-ELT is built and CODEX gets strapped to the telescope first — observations for the Sandage-Loeb experiment could begin in 2018. That would make the first real-time detection of the universe's expansion complete by 2040 — a fascinating find.

Web extra

The astrocomb isn't geared only toward dark-energy surveys. Astronomers could also use it to tease out the existence of earthlike planets that orbit other stars. In fact, this is a research area some astronomers are focusing on now. For more about the astrocomb's importance for exoplanet surveys, visit **www.Astronomy.com/toc**.

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

June 09

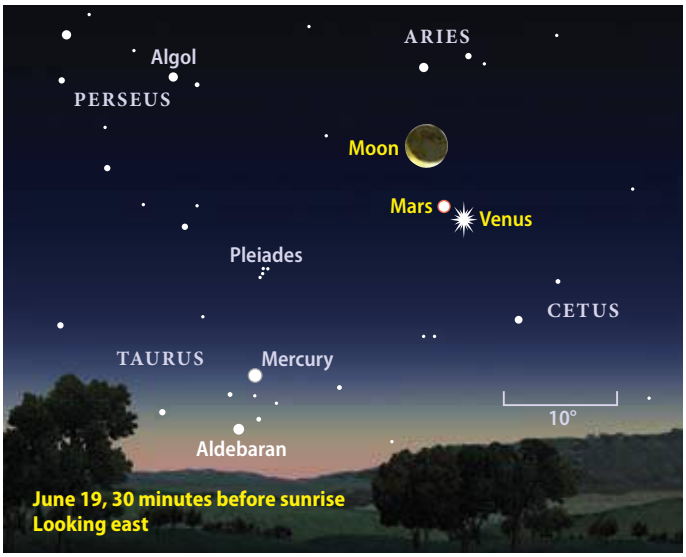
Venus blazes before dawn

Both inner planets gather in June's morning sky. Mercury and, in particular, Venus put on fine displays as twilight commences. The warm evenings typical of June offer great conditions to show off the solar system's most beautiful planet, Saturn. Go ahead and invite some neighbors over for their first view of the ringed planet through a telescope. Meanwhile, the overnight hours belong to Jupiter, Uranus, Neptune, and Pluto.

As darkness falls, one lone planet graces the star-filled sky. **Saturn** stands more than one-third of the way from the southwestern horizon to the zenith shortly after sunset. It sets shortly before 2 A.M. in early June and by midnight at month's end.

At magnitude 1.0, Saturn matches the bright star Spica in the constellation Virgo. Blue-white Spica lies about 40° to Saturn's upper left. The planet's closer neighbor, Leo's star Regulus, shines 15° to Saturn's lower right. Appearances can be deceiving, however. The planet currently lies only 885 million miles from Earth, while Regulus shines across 450 trillion miles (78 light-years), some 500,000 times farther away. And Spica lies even farther off, at a staggering 1.5 quadrillion miles (260 light-years).

On June 5, Saturn's orbit brings the planet to a location called eastern quadrature. At this time, the angle formed by a line from Earth to the Sun to Saturn equals 90°. This proves to be of more than academic interest. At quadrature, Saturn's shadow casts its widest swath onto the farside of the rings. It lends a distinct three-dimensional look to Saturn's telescopic appearance.



Venus slides 2° from Mars before sunrise June 19. This conjunction looks especially impressive because a crescent Moon lies nearby. *Astronomy*: Jay Smith

A crescent Moon kept company with Venus (just above) and Mercury in the sky above Australia March 6, 2008. A similar gathering awaits northern observers this month. Mike Salway

The rings themselves appear narrow this month. They tilt 4° to our line of sight June 1 and 3° June 30. This means they span approximately 40" east-to-west and just 3" north-to-south. The rings will tip edge-on to our line of sight in early September, about 3 weeks after the Sun passes through Saturn's ring plane. Unfortunately, Saturn lies low in evening twilight during August and disappears in the Sun's glare in September.

Most of Saturn's moons orbit in the same plane as the rings. Our practically edge-on view of the system means the moons crisscross in front of and behind the planet during each orbit. The different

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36 Venus rules the morning sky
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42 Comet search
43 Locating asteroids
43 Jupiter points to Neptune

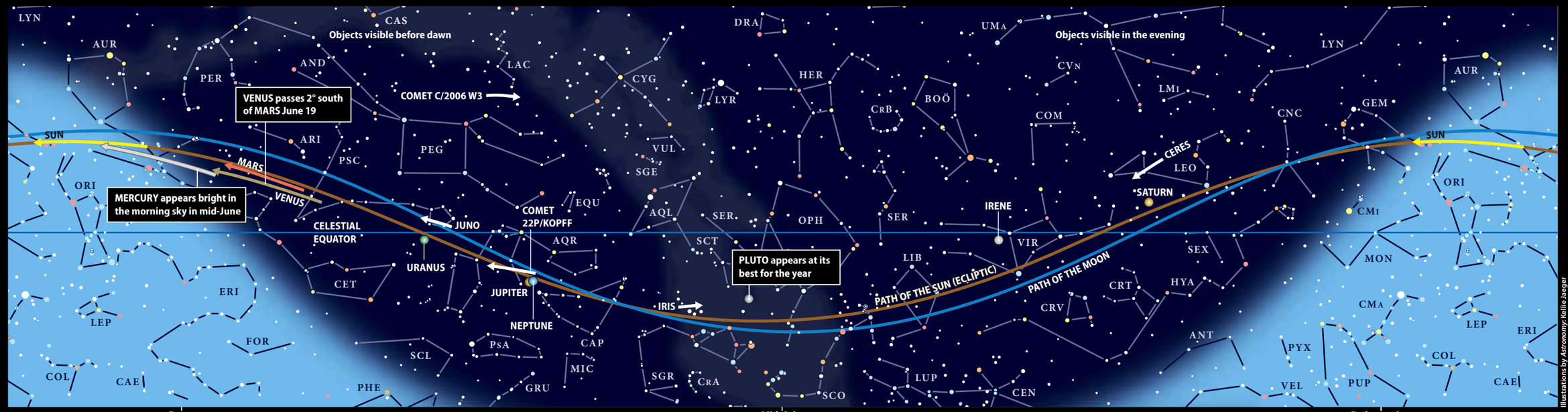
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in June 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets

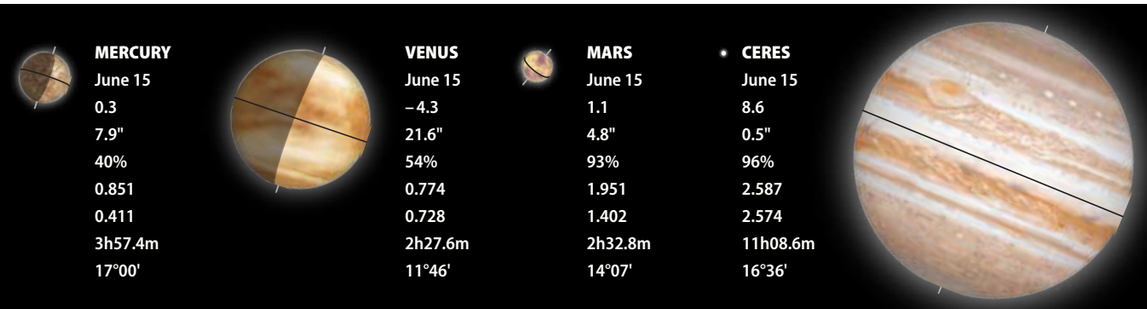


Illustrations by *Astronomy*: Kellie Jaeger

MOON PHASES

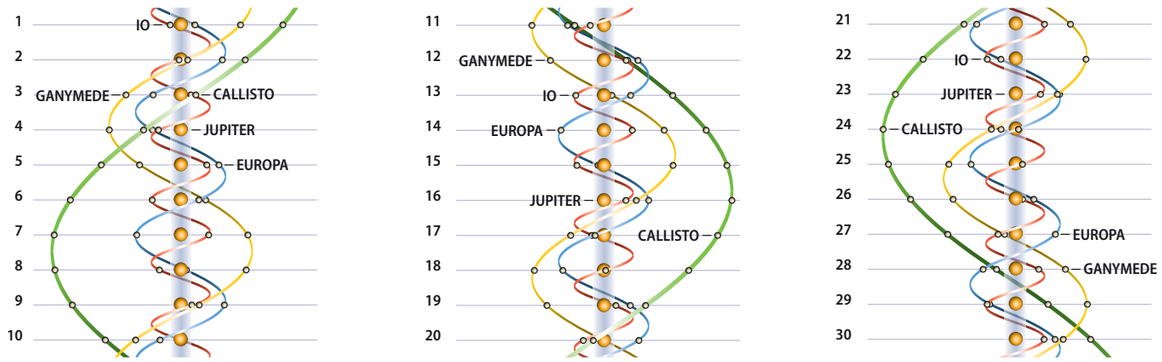
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	June 15	June 15	June 15	June 15	June 15	June 15	June 15	June 15	June 15
Magnitude	0.3	−4.3	1.1	8.6	−2.6	1.0	5.8	7.9	13.9
Angular size	7.9"	21.6"	4.8"	0.5"	43.7"	17.5"	3.5"	2.3"	0.1"
Illumination	40%	54%	93%	96%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.851	0.774	1.951	2.587	4.516	9.510	20.117	29.545	30.659
Distance (AU) from Sun	0.411	0.728	1.402	2.574	5.059	9.415	20.099	30.030	31.660
Right ascension (2000.0)	3h57.4m	2h27.6m	2h32.8m	11h08.6m	21h57.6m	11h09.8m	23h47.9m	21h54.6m	18h08.6m
Declination (2000.0)	17°00'	11°46'	14°07'	16°36'	−13°22'	7°39'	−2°08'	−13°08'	−17°39'



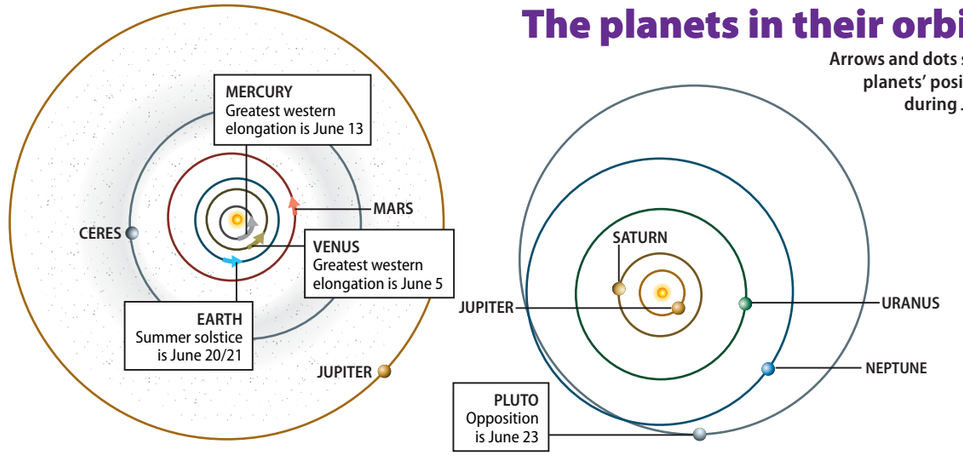
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during June.



StarDome

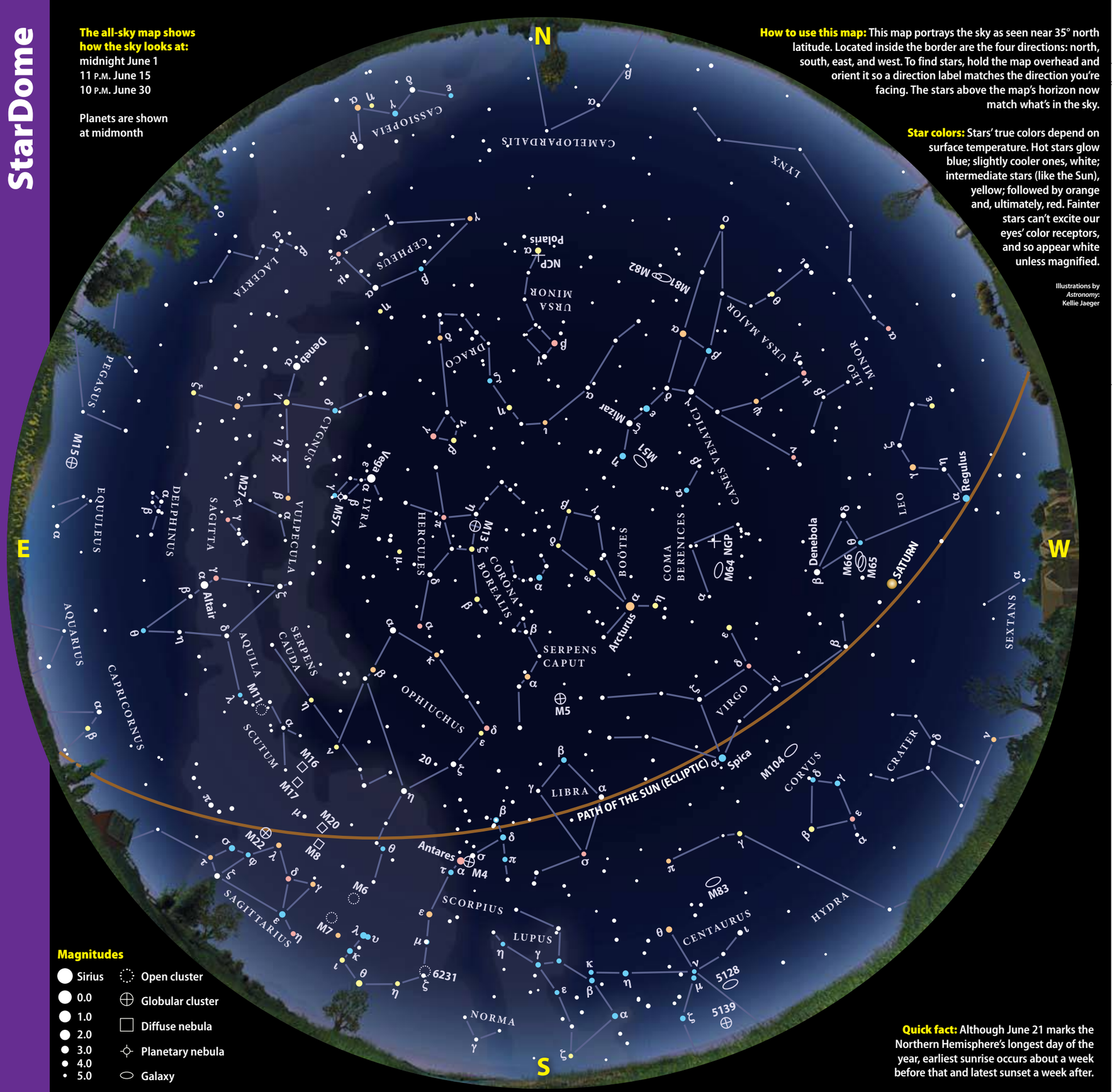
The all-sky map shows how the sky looks at:
midnight June 1
11 P.M. June 15
10 P.M. June 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Kellie Jaeger



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: Although June 21 marks the Northern Hemisphere's longest day of the year, earliest sunrise occurs about a week before that and latest sunset a week after.

June 09

Note: Moon phases in calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Calendar of events

5 Venus is at greatest western elongation (46°), 5 P.M. EDT

6 The Moon passes 0.6° north of Antares, midnight EDT

7 Full Moon occurs at 2:12 P.M. EDT

10 The Moon is at apogee (252,144 miles from Earth), 12:04 P.M. EDT

13 Mercury is at greatest western elongation (23°), 8 A.M. EDT

The Moon passes 3° north of Neptune, noon EDT

The Moon passes 3° north of Jupiter, 2 P.M. EDT

15 Jupiter is stationary, 4 P.M. EDT

L Quarter Moon occurs at 6:15 P.M. EDT

The Moon passes 0.4° south of asteroid Juno, 7 P.M. EDT

16 The Moon passes 6° north of Uranus, 2 A.M. EDT

19 Venus passes 2° south of Mars, 10 A.M. EDT

The Moon passes 6° north of Mars, 1 P.M. EDT

The Moon passes 8° north of Venus, 1 P.M. EDT

21 Summer solstice occurs at 1:46 A.M. EDT

The Moon passes 7° north of Mercury, 5 A.M. EDT

22 Asteroid Vesta is in conjunction with the Sun, 8 A.M. EDT

Mercury passes 3° north of Aldebaran, 10 A.M. EDT

N Moon occurs at 3:35 P.M. EDT

23 Pluto is at opposition, 4 A.M. EDT

The Moon is at perigee (222,460 miles from Earth), 6:39 A.M. EDT

27 The Moon passes 7° south of Saturn, 10 P.M. EDT

29 F Quarter Moon occurs at 7:28 A.M. EDT

Special observing date

19 A waning crescent Moon lies near Venus and Mars in the eastern sky before dawn.

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

— *Continued from page 36*
orbital period of each moon can result in some rare and intriguing moon alignments.

Point your telescope at Saturn the evening of June 10, and you'll see a fine example. To the east of the rings, four moons appear stacked in a neat parallelogram shape. Tethys, Dione, Rhea, and Enceladus all lie within a 9"-diameter circle. (At 12th magnitude, Enceladus appears markedly fainter than the trio of 10th-magnitude moons.)

If you start watching right after nightfall, you'll see the parallelogram distort over a couple of hours as Dione and Rhea head westward. This pair also meets June 24 when they apparently skim north of the rings while separated by less than 2". You can find other interesting alignments using planetarium software or, even better, simply by observing Saturn every clear night.

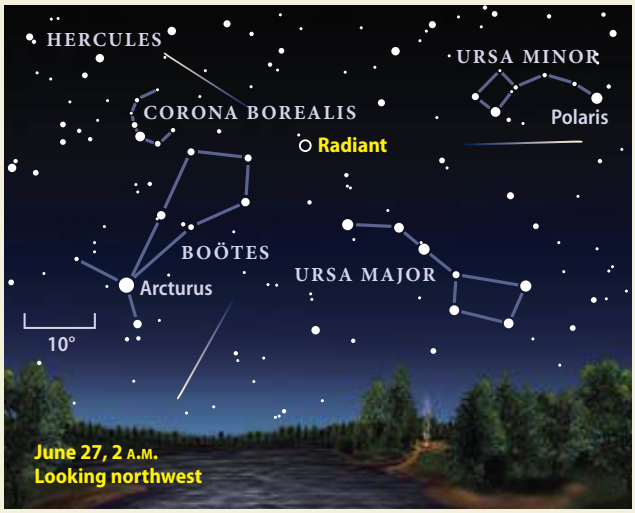
Any telescope will reveal Saturn's brightest moon, Titan. This 8th-magnitude point of light appears conspicuous when it stands clear of the planet's disk and rings. But the most exciting times to view Titan come when it enters Saturn's shadow or its dark shadow crosses Saturn's bright cloud tops. Three such events occur in June, and North American observers will have ringside seats.

Titan slides into Saturn's shadow June 8 at 12:34 A.M. CDT (10:34 P.M. PDT June 7). It takes 16 minutes for the shadow to totally engulf the moon in darkness. In eastern North America, Saturn sets before the eclipse starts, but observers farther west will have good views. Saturn's shadow now extends well east of the planet, so Titan lies a healthy 7" southeast of Saturn's limb.

A week later, Titan's black shadow crosses Saturn's golden disk. The shadow transit starts at 11:40 P.M. EDT June 15 (7:40 P.M. PDT). East Coast

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire.* **Alister Ling** *is a meteorologist for Environment Canada in Edmonton, Alberta.*

Meteor watch



The June Boötids peak before dawn June 27. The Moon will be gone from the sky after midnight. *Astronomy*: Roen Kelly

A possible herd of meteors for June nights

Some meteor showers perform consistently year after year. Others are unpredictable — like the June Boötids. Observers saw only marginal activity between 1928 and 1997, so this shower received scant attention. Yet it produced more than a meteor per minute in 1998, and another nice display occurred in 2004.

The June Boötids should peak before dawn June 27, although watching a night or two before and after wouldn't hurt. The radiant lies in the constellation Boötes the Herdsman, which remains on view nearly all night. The waxing crescent Moon sets before midnight, leaving the sky dark for excellent meteor viewing.

These meteors arise from debris shed by Comet 7P/Pons-Winnecke. Activity this year depends on whether Earth passes through a thick trail of comet debris, and no one knows if it will.

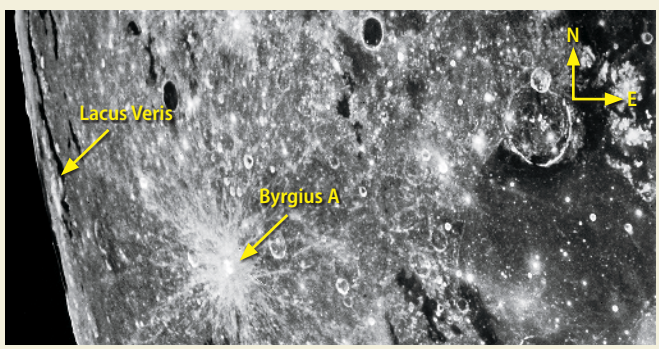
Rising Moon

Moon-watching in the daytime

Break free of the mindset that astronomy happens only at night. Instead of fighting to stay up late or get up early, plan to spend a few minutes observing before heading off to work. A spotting scope that takes a minute or two to set up and take down can provide a quick view of the Moon. What better way to put you in a positive mood to start the day?

An added benefit: The bright-blue sky reduces glare from the Moon itself. Because our focus this month is on "crater splash" and Mare Orientale, you don't need a dark background. Although our starting point lands on the night of Full Moon (June 7), the Moon moves into the morning sky within a couple of days.

The lava-filled crater Grimaldi stands out near the Moon's western limb beginning at full phase. You can spot it just south of the lunar equator. Scanning farther south will bring you to the bright splotch known as Byrgius A. All recent large lunar impacts ejected material with a much lighter color than the dark lava that fills the basins. A constant stream of energetic particles from the Sun slowly darkens these bright rays, so astronomers can tell that Byrgius A formed relatively recently. Of course, "young" on the Moon still means a billion or so years ago.



The farside's Mare Orientale peeks into view after June 7's Full Moon. Look for Lacus Veris, a dark expanse that marks the region between Orientale's second and third rings of mountains. *Consolidated Lunar Atlas*/UA/LPL

In the days after Full Moon, the normally hidden outskirts of Mare Orientale gradually swing into view as the western limb appears to rotate slightly toward us. You can't miss the long, narrow, and dark-gray stretch of mare called Lacus Veris. It lies between the second and third rings of the colossal Mare Orientale impact basin. Those rings show up in profile on the lunar limb until around June 19.

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Saturn (southwest)	Saturn (west)	Mercury (east)
		Venus (east)
		Mars (east)
		Jupiter (south)
		Uranus (southeast)

observers will see the transit's early stages while those out west will see the middle stages of the nearly 6-hour event.

Titan returns to the farside of Saturn the evening of June 23. The moon dives into Saturn's shadow starting at 11:45 P.M. CDT (9:45 P.M. PDT), once again after Saturn has set along North America's East Coast. Titan then lies 5" off Saturn's southeastern limb as it begins to fade.

Dwarf planet **Pluto** reaches opposition and peak visibility June 23. In Pluto's case, however, peak visibility doesn't mean much. At magnitude 13.9, the distant object is hard to spot visually even under the best conditions. You'll likely need at least a 10-inch telescope, although a smaller scope with a CCD camera attached will also work. Take images a few nights apart, and Pluto's motion relative to the background stars will betray its location.

You can find Pluto in northern Sagittarius, about 3.5° north of 4th-magnitude Mu (μ) Sagittarii. A horizontal line of three stars will serve as a guide. The stars shine between magnitude 5.5 and 6.3 and span some 3°. Pluto wanders westward this month, passing due south of the middle star in the line.

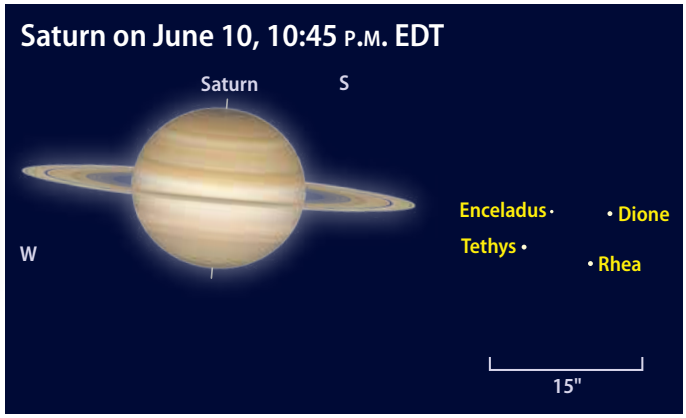
In mid-June, brilliant **Jupiter** rises shortly after midnight local daylight time. Gleaming at magnitude –2.6, it dominates its surroundings in eastern Capricornus. The planet's disk measures 44" across the equator, some 3" greater than its polar diameter. This noticeably squashed appearance arises from Jupiter's gaseous nature combined with its fast rotation.

Jupiter is a fine object in any telescope. Small scopes easily show two dark parallel belts, one on either side of the planet's equator. Larger scopes reveal more atmospheric features. You'll see lots of turbulence in the equatorial belts, particularly along their boundaries where the relative wind speeds peak.

Jupiter's rapid rotation carries these features across the planet's disk in just a few hours. You should notice changes in position in as few as 10 minutes. This alone makes Jupiter a favorite target among observers. Features show up easier on Jupiter than on any other planet, thanks to their high contrast and the planet's giant disk.

Also look for Jupiter's four bright moons. Galileo first saw them nearly 400 years ago with a 1.5-inch telescope of lower quality than any available today. The moons glow bright enough that you could see them without optical aid if Jupiter weren't in the vicinity.

Neptune makes a good target for binoculars, although you'll need a telescope to spy



A parallelogram of four moons greets Saturn observers June 10. Look for Tethys, Dione, Rhea, and Enceladus to change relative positions within just a few minutes. *Astronomy*: Jay Smith

Comet search

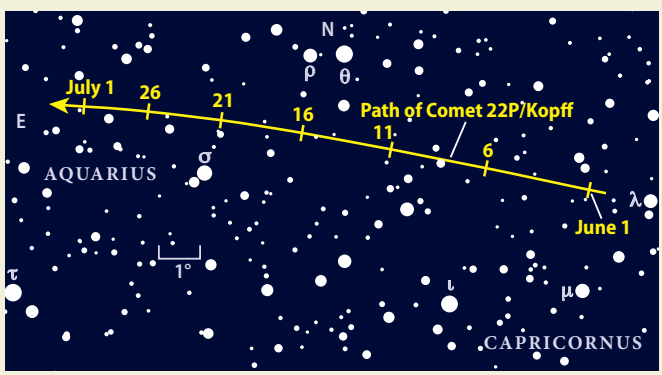
Cap the night with Comet Kopff

Wouldn't it be great if we could schedule bright comets to arrive facing Earth's evening side? The universe delivers on its own schedule, however. This month, the dependable performer 22P/Kopff lies in the morning sky near Jupiter. Considering how briefly the Sun dips below the horizon around the summer solstice, you may be pulling an all-nighter anyway.

Comet Kopff should glow between 8th and 9th magnitude. That makes it a nice target even in small telescopes as long as you're away from city lights and the Moon lies below the horizon. June offers two good observing windows: the first week and the last 10 days. Once you've picked out the area between Jupiter and the Y-shaped asterism of Aquarius' Water Jar, use the chart to home in on the comet.

Medium to high power will deliver the best views of the comet's structure. Its stubby tail should fade quickly on its western flank while its well-defined eastern edge comes from the solar wind pushing back the comet's dust envelope. Check to see if the nearly stellar false nucleus is poking through the cocooning coma.

Because this dirty snowball never gets closer to the Sun than the orbit of Mars, it sheds gas and dust at a slower, steadier pace than most comets. German astronomer August Kopff discovered this comet photographically in 1906. Completing an orbit every 6.4 years, 22P/Kopff is now on its 16th recorded return. Still, you should take the time to observe it now. During its next apparition, Kopff will be on the other side of the solar system from Earth and not appear as nice.



Comet 22P/Kopff should glow around 8th magnitude in June as it plies the dim background of Aquarius the Water-bearer. *Astronomy*: Jay Smith

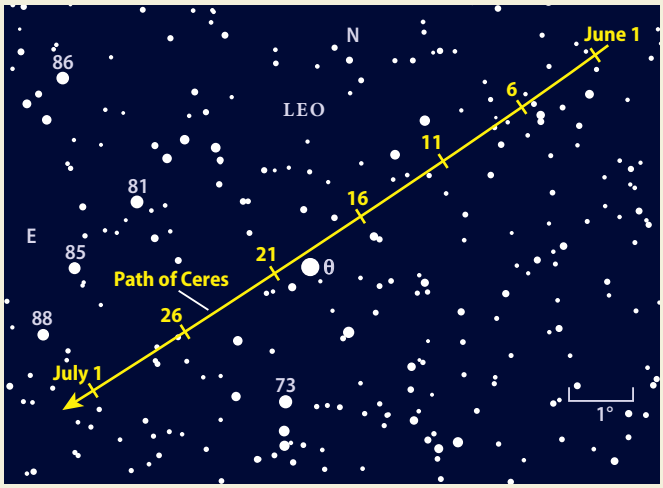
Locating **asteroids**

Simply seeing Ceres

If once-a-month excursions to a dark sky leave you wanting more eyepiece time, you might try observing some brighter objects from the backyard. Finding and tracking a bright asteroid fits the bill. This month's best is 1 Ceres, which is nicely placed in the western evening sky. You can find it crossing the hindquarters of Leo the Lion, near the 3rd-magnitude star Theta (θ) Leonis.

You can't miss Ceres from June 18 to 21 because it shares the same low-power field with Theta. Another field star, this one at 7th magnitude, locks the orientation and scale to make recording Ceres' progress from night to night a snap. With only a few exceptions, the other background stars glow fainter than Ceres, which fades from magnitude 8.4 to 8.7 in June. Use a small scope to peg this space rock, which measures some 600 miles across. Binoculars will show you Ceres, but a city's sky glow will hide it from view.

Ceres reached opposition in February, and it soon will be lost in the Sun's glare as Earth heads to the other side of the solar system. NASA's Dawn spacecraft will give us our first close-up look at this dwarf planet in 2015.



Ceres tracks through Leo this month, not far from the 3rd-magnitude star Theta (θ) Leonis. A small telescope will bring the solar system's biggest asteroid into view. *Astronomy*: Jay Smith

its tiny blue-gray disk. The fabulous proximity of Jupiter gives away 8th-magnitude Neptune's location this month. On June 1, Neptune lies 0.5° northwest of Jupiter.

Jupiter's easterly motion causes the gap to widen until June 15, when its apparent eastward motion stops and the giant planet starts moving to the west. This retrograde motion, which Neptune mimics at a slower pace, brings both planets closer to the 5th-magnitude star Mu Capricorni. In July, the planets will straddle this star.

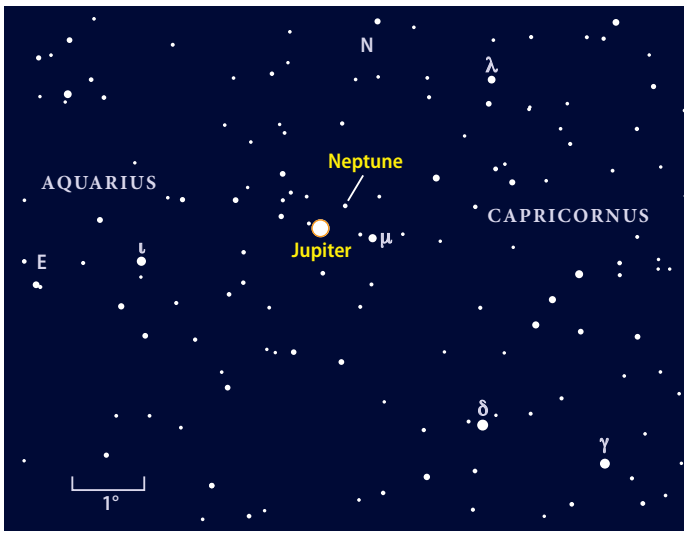
A little more than an hour after Jupiter and Neptune rise, **Uranus** pokes above the eastern horizon. Binoculars reveal the planet easily once it climbs higher by 3 A.M. or so. Uranus lies in Pisces, due south of the Circlet asterism's eastern edge. You can find it less than 1° north of the 5.5-magnitude star 20 Piscium. At magnitude 5.8, Uranus glows slightly fainter than the star. Through a telescope, the planet shows a 3.5"-diameter disk with a distinctive blue-green hue.

Early morning risers will have glorious views all month. Brilliant **Venus** leads the way. It reaches greatest elongation June 5, when it lies 46° west of the Sun. The planet shines at magnitude –4.4 that morning and appears nearly 15° high in the east an hour before the Sun rises. Although Venus dims slightly during June, Northern Hemisphere observers will see it climb higher in the predawn sky.

The view of Venus through a telescope proves no less impressive. On June 1, the planet spans 25" and appears 47 percent lit. By month's end, the disk's size has fallen to 19" and its phase has waxed to 61 percent illumination.

Venus passes 2° south of **Mars** June 19. Coincidentally, a waning crescent Moon joins the pair in a picturesque arrangement that same morning. Venus stands 15° above the eastern horizon at 4:30 A.M. local daylight time with Mars to its upper left and the Moon 7° above the pair. It's a stunning sight as dawn breaks.

Let Earth turn a little bit more, and you'll find Mercury piercing the twilight glow. Mercury shines at magnitude –0.1, Mars at magnitude 1.1, and Venus steals the show at magnitude –4.3.



Jupiter points the way to Neptune throughout June. The distant outer planet lies within 0.5° of brilliant Jupiter June 1, and they don't stray much farther all month. *Astronomy*: Jay Smith

Mars shows little through a telescope this month, spanning only 5". It will be late autumn before its appearance improves significantly.

Mercury fares better. It reaches greatest western elongation June 13. Because it lies about half as far from the Sun as Venus, its angular distance is also about half (23°). You'll find 0.4-magnitude Mercury 6° high in the east-northeast 30 minutes before sunrise. A telescope reveals the planet's 8"-diameter disk and crescent phase. Mercury appears half-lit June 19. It remains on view through the end of June, when it stands 5° high half an hour before sunrise and shines at magnitude –0.9.

Earth's summer solstice arrives at 1:46 A.M. EDT June 21. The Sun then lies farthest north in our sky, and summer officially begins in the Northern Hemisphere.

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

Did a meteorite impact trigger a martian volcano?

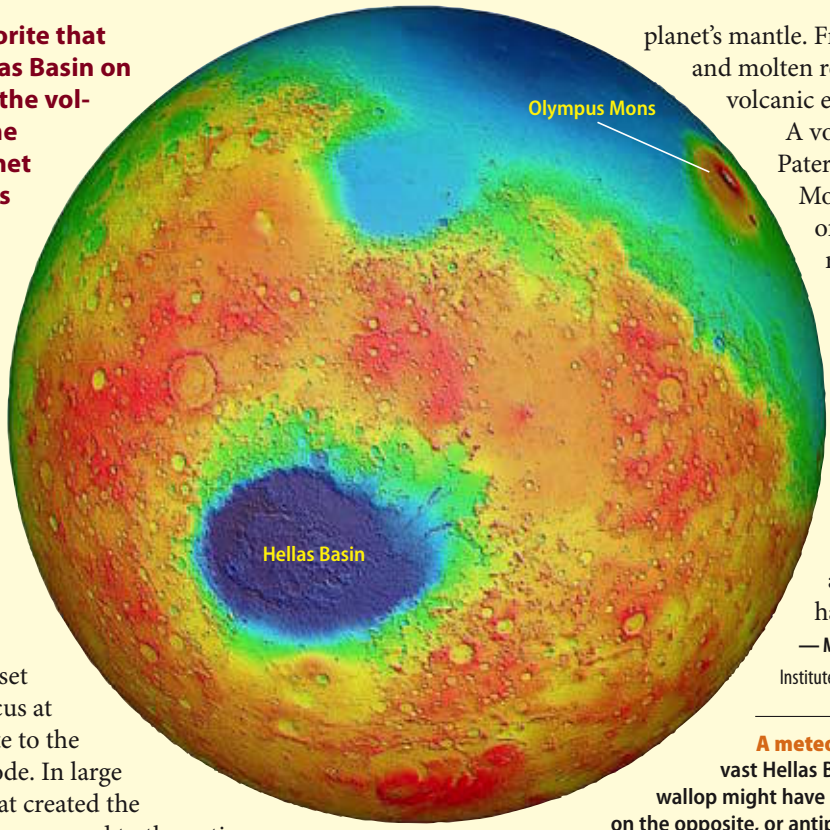
Q: Could the meteorite that formed the Hellas Basin on Mars have triggered the volcanic eruptions on the other side of the planet that created Olympus Mons? — Frank Thoma, Palm Bay, Florida

A: It is possible for a large meteorite strike to trigger volcanic eruptions. However, the Hellas Basin's location disproves any connection to the volcano Olympus Mons.

Meteorite strikes on rocky worlds like Mars set off shock waves that focus at the spot exactly opposite to the impact, called its antipode. In large impacts, like the one that created the Hellas Basin, the energy conveyed to the antipode by shock waves can be intense enough to fracture the crust and completely melt deeper rock below in the planet's mantle. Fractured surface rock and molten rock beneath can trigger volcanic eruptions.

A volcano called Alba Patera, north of Olympus Mons, lies at the antipode of Hellas Basin. Some researchers suggest, based on results from computer simulations, that the Hellas impact created Alba Patera. Olympus Mons, however, is about 1,056 miles (1,700 kilometers) from the Hellas Basin's antipode, so it probably has a different origin.

— Margarita M. Marinova, California Institute of Technology, Pasadena



A meteorite impact carved out the vast Hellas Basin on Mars. The global wallop might have set off volcanic eruptions on the opposite, or antipodal, point from Hellas. However, Olympus Mons does not lie at the antipode of the Hellas Basin and probably has a different origin.

NASA/GSFC/JPL/MOLA Project/Malin Space Science Systems

STARLIGHT, HOW BRIGHT?

Q: In stellar magnitude estimates, why do larger numbers represent dimmer objects? Shouldn't it be the other way around? — Len and Carolyn Strilchuk, Vernon, British Columbia

A: Stellar magnitude estimates use larger numbers for dimmer celestial objects because the system's originator, Greek astronomer Hipparchus, decided to do it that way in the second century B.C. Hipparchus considered the brightest stars in the sky to be the largest ones and therefore ranked them "of the first magnitude," or size, in his system. Dimmer stars, similar to the runners up in a marathon, rank second, third, and so on in order of diminishing size.

Sirius in Canis Major was the brightest star in the Greek sky. Hipparchus chose it as the defining example of a 1st-magnitude star. He then used it to identify the 20 brightest stars in his catalog.

Hipparchus then ranked the other stars down to magnitude 6, at the limit of naked-eye visibility. The catalog included only the "fixed" background stars and excluded celestial wanderers like the planets and the Sun and Moon.

Since Hipparchus' lifetime, scientists have modernized the old magnitude scale while retaining the "bigger is dimmer" ranking system. The scale now describes star brightness more precisely to multiple decimal places. The system also includes zero and negative numbers to describe objects brighter than 1st magnitude. For example, the brightest star we can see from Earth, the Sun, shines at magnitude –26.73. **— Raymond Shubinski,** Contributing Editor

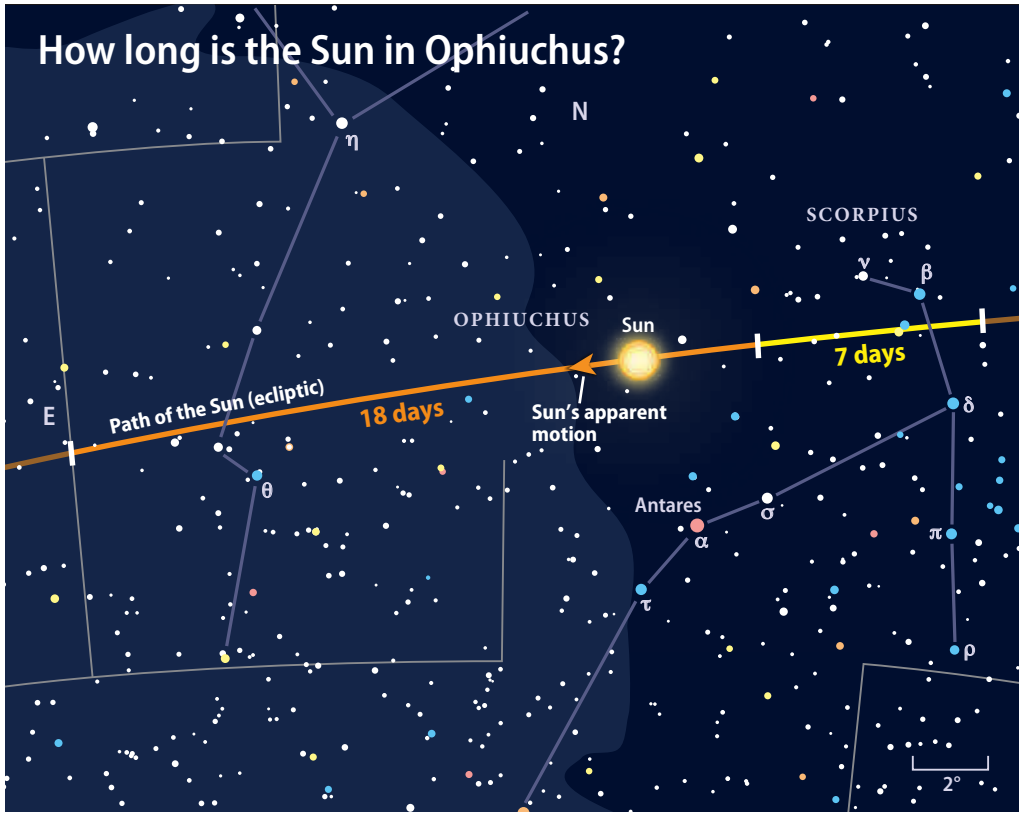
ZODIACAL INSIGHTS

Q: The constellation Ophiuchus lies partly on the ecliptic, so why isn't it considered one of the zodiacal signs? — **Steve Buckley,** Johannesburg, South Africa

A: In the second millennium B.C., the Babylonians divided the sky into 12 equal segments along the ecliptic, which traces the apparent annual path of the Sun through the stars as seen from Earth. They named each 30°-wide segment after a nearby star pattern. This established the 12 signs of the zodiac, which comes from the Greek *zodiakos*, meaning "circle of animals."

The star pattern (constellation) Ophiuchus does lie along the ecliptic. However, **Ophiuchus is not part of the astrological zodiac because it first appeared in sky maps long after the Babylonians created the 12 signs and named them after constellations recognized at that time.** Although 13 modern constellations intersect the ecliptic to form the astronomical zodiac, only 12 are associated with the signs of the astrological zodiac.

The borders of the astrological signs do not correspond exactly to the borders of the constellations after which they were named. For example, the 30° sky segment associated with the astrological sign Scorpio includes stars from both Scorpius the Scorpion and Ophiuchus the Serpent Bearer. In fact, the Sun spends more time coursing through Ophiuchus (about 18 days) than it does in Scorpius (7). — **Geoff Chester,** U.S. Naval Observatory, Washington, D.C.



The region of the sky associated with the astrological sign Scorpio includes stars from both Scorpius the Scorpion and Ophiuchus the Serpent Bearer. Surprisingly, the Sun spends more time in Ophiuchus even though it's not among the 12 constellations of the astrological zodiac. *Astronomy:* Roen Kelly

THE BAR SCENE

Q: How do the bars in barred spirals form? — **Terry Burke,** Marquette, Nebraska

A: Galactic bars form when stars in circular orbits around a galaxy's center start to stretch out into more oval, or elliptical, trajectories. The stars then disturb the orbits of other stars, further reinforcing the bar. It remains unclear what triggers those first stars to shift into elliptical orbits.

The bar's lopsided mass also draws interstellar gas out of circular orbits. This can cause gas streams to collide, triggering compression and heating. Astronomers observed such "shocked" gas in the Milky Way and hypothesized the presence of a galactic bar — about 28,000 light-years long — even before they could directly observe one. — **Robert Benjamin,** University of Wisconsin-Whitewater

DARK MATTERS

Q: Could large numbers of black holes account for much of the "dark matter" estimated to exist in our universe? — **Jeff Wise,** Louisville, Kentucky

A: No, because the universe never had the raw material to grow enough black holes to account for current estimates of dark matter.

Dark matter emits no light, so it is invisible. However, astronomers can detect it indirectly because of its gravitational influence on normal matter. Scientists estimate that about 23 percent of the universe consists of exotic "cold dark matter" particles. By contrast, only about 5 percent of the universe consists of normal, or "baryonic," matter, like protons and electrons. Baryons make up the visible universe of stars and planets.

Black holes form when baryonic matter concentrates to form a superdense mass with gravity so intense that not even light can escape its grasp. The biggest black holes known contain millions to billions of times the Sun's mass.

Observations and theory indicate that the Big Bang, which created all the matter in the universe, could not have forged enough baryons to account for dark matter. Even if all the Big Bang's baryons condensed into black holes, they would still not equal the universe's total dark matter. — **Eliot Quataert,** Theoretical Astrophysics Center, University of California at Berkeley

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Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Astroimager profile

Adam Block's awesome universe

From an Arizona mountaintop, Adam Block introduces amateur astronomers to cutting-edge imaging.

by Tom Polakis

Adam Block, a top astroimager, is seen here with the Mount Lemmon SkyCenter's 24-inch Ritchey-Chrétien telescope. Block used it to capture all astroimages in this article. Courtesy Adam Block

Adam Block is passionate about astronomy, and he's contagious. Block leads Mount Lemmon SkyCenter's SkyNights program for up to 20 people nightly. The SkyCenter, 17 miles from Tucson as the crow flies, also offers an all-night Visiting Astronomer session and various other programs. Block spreads his astronomy infection to willing participants.

Mount Lemmon is a destination for hikers, campers, birders, geologists, botanists, and even skiers (the mountain hosts the nation's most southerly ski resort and gets some 180 inches of snow annually). Block, however, sees the location as a "destination in and of itself," and astronomy is yet another great reason to visit.

At age 36 with a Bachelor of Science in both astronomy and physics, Block has a mission: "promote public outreach in astronomy and offer premier access to the universe." The preeminent astroimager gained his reputation from the public program he brought to success at Kitt Peak National Observatory.

He was the lead observer and educator with Kitt Peak's public programs for 9 years. Today he is known for his 40 images in NASA's Astronomy Picture of the Day, frequent contributions to *Astronomy*'s "Reader Gallery," and workshops and lectures at both astronomy clubs and conferences. Block also shares his image processing skills in his 4-volume DVD series *Making Every Pixel Count*.

The spiral galaxy M77 is roughly 47 million light-years away in the constellation Cetus. It has a bright core and extremely faint peripheral spiral arms. Adam Block/Mount Lemmon SkyCenter/University of Arizona

Teaching others

Tonight Block, the SkyCenter's Public Observing Programs coordinator, will bring 10 nascent sky gazers closer to the universe than they've ever imagined. The coordinator begins the evening with an introductory "Astronomy 101" accompanied by a light dinner at the SkyCenter's Learning Center. Before heading to the dome, visitors learn the tools of the trade along with an appreciation of time, scale, and the concept of billions. After this preparation for the marvels that lie ahead, they step outside and walk to the dome. Most have never viewed anything through a telescope.

As they head for the telescope the SkyNights group will use, Block points out the Catalina Sky Survey telescope, which is leading the search for near-Earth asteroids. Meanwhile, the Korea Astronomy and Space Science Institute's 1-meter robotic telescope springs to life.

Tom Polakis *is an aerospace engineer living in Tempe, Arizona, who is interested in visual observing and sky photography.*

∧ The dome that houses the SkyCenter's 24-inch telescope dwarfs the scope. Soon a 32-inch scope will replace the 24-inch instrument. Inset: The RC Optical Systems 24-inch scope is silhouetted against the dark Arizona sky. Tom Polakis

> The Sombrero Galaxy (M104) is a nearly edge-on spiral galaxy located some 29 million light-years distant. Can you see the other galaxies in this image? A number cluster to the left of M104, and one sits to the bottom right. Adam Block/ Mount Lemmon SkyCenter/University of Arizona

One of the largest domes atop the 9,157-foot (2,791 meters) mountain is where Block will bring his group face to face with the awesome universe. They'll observe spiral galaxies, binary star systems, star clusters, stellar nurseries, planetary nebulae, supernovae, planets, and, if in view, a Moon so close you can almost walk on it. From this lofty vantage point, Block describes sunset phenomena while directing the group to Venus and

The Eagle Nebula (M16) is an emission nebula some 7,000 light-years away. An open cluster with active star formation floats within the nebula. Adam Block/Mount Lemmon SkyCenter/University of Arizona

NGC 5364 is a beautiful face-on galaxy with long spiral arms. It's located some 70 million light-years distant in the constellation Virgo. Adam Block/Mount Lemmon SkyCenter/University of Arizona

Jupiter with a quick lesson on their assigned binoculars.

The Milky Way is already apparent in early twilight. Before entering the dome, Block uses his laser pointer to connect the dots to make Cygnus into a swan. This dome previously housed a damaged 40-inch telescope. Its size dwarfs the 24-inch Ritchey-Chrétien telescope that RC Optical Systems loaned pending completion of the SkyCenter's 32-inch. Even with the addition of a warm room and tonight's group, the cavernous dome has plenty of space for others. Block takes a moment to demonstrate time and date alignment on the planispheres that local retail company Starizona donated.

Block instructs a visitor to move the telescope to Jupiter using *TheSky* software. The guests are amazed with their unprecedented view of the gas giant, and the visiting scope operator is impressed with himself. The next stop is Albireo. After viewing this single star in Cygnus with their naked eyes just moments earlier, the guests now understand what telescope magnification can do as they split Albireo into the blue and gold pair.

Never a fan of "checklist" observing, Block rotates between naked-eye, binocular, and telescopic viewing. And he always includes explanations. "There should be no sitting and waiting while

∧ The Witch's Broom Nebula (NGC 6960) is the western end of the much larger Veil Nebula, a supernova remnant 6 times the angular size of the Full Moon. The supernova remnant is about 1,400 light-years distant toward Cygnus. Adam Block/Mount Lemmon SkyCenter/University of Arizona

< NGC 7354 is a planetary nebula some 4,200 light-years away in Cepheus. At the end of a red giant's life, the star sheds its outer layers. Those outer layers then glow from the leftover white dwarf star's radiation. Adam Block/Mount Lemmon SkyCenter/University of Arizona

> The Cat's Eye Nebula (NGC 6543) is a structurally complex planetary nebula with knots and jets. This image shows both the bright inner nebula and the extended halo of material. Adam Block/Mount Lemmon SkyCenter/University of Arizona

others are observing," says Block as he leads his observers, with their newly honed binocular and planisphere experience, outside to locate binocular treats M13, M11, and the Coathanger asterism. By now, the Milky Way blazes across the sky overhead.

Back inside the dome, guests take turns at the telescope witnessing the stunning number of stars in globular cluster M13. Block continuously teaches, explains, and nurtures newfound interests in astronomy.

The final object guests observe is the edge-on spiral galaxy NGC 891. Then Block brings the group to the monitor to see his images of each of the 15 objects they viewed that night. After hearing explanations of CCD imaging, the software and hardware involved, and the amount of time each image takes, these new observers are quite content with their newly found visual treasures. Block leaves them with an encore view of the color-contrasting double star system Iota (ι) Cancri, and they leave him with five-star ratings.

Premier imaging

The Visiting Astronomer program begins soon after the SkyNights guests depart. Utilizing Mount Lemmon's dark mountaintop site, the SkyCenter's equipment,

Two interacting galaxies make up Arp 273 (UGC 1810) some 200 million light-years away. Gravitational interactions between the two galaxies create tidal tails and other distortions that make for an intriguing display for onlookers. Adam Block/Mount Lemmon SkyCenter/University of Arizona

Supernova remnant Cassiopeia A sits about 11,000 light-years away. While it's the brightest radio source in the sky, it's extremely faint optically. Astronomers recently observed the supernova's light echo and determined the supernova was a type IIb — a massive star that undergoes a violent collapse and then explosion. Adam Block/Mount Lemmon SkyCenter/University of Arizona

Gyulbudhagian's Nebula is a variable reflection nebula related to the star PV Cephei. For more than 2 years it's been too faint to see with telescopes as large as 25 inches. On an autumn night, Adam Block turned the SkyCenter's 24-inch scope on the nebula and created this 190-minute image. Adam Block/Mount Lemmon SkyCenter/University of Arizona

and Block's experience, guests produce professional-grade astroimages.

There's a vacancy tonight, so Block takes a 10-minute exposure of Gyulbudhagian's Nebula. Even though observers could see this object with a 10-inch aperture only 2 years ago, the variable nebula has recently been too faint for telescopes as large as 25 inches. Block's 10-minute image brings it out of hiding with incredible detail, but he doesn't stop there. With his mantra in mind — promote public outreach in astronomy and offer premier access to the universe — Block captures and compiles a 190-minute image that totally knocks the socks off this 30-year amateur astronomy veteran.

Without a Milky Way to spark curiosity under light-polluted skies, astronomy is a difficult hobby to promote. It's much different to view an object on a monitor in the comfort of home than to peer billions of miles into space on a dark mountaintop. One such magnified view through a telescope or a naked-eye view of a dark, starry sky is often all it takes to step into a lifelong love of amateur astronomy. And Block knows how to flaunt the majesty of the universe and excite new observers.

See more of Adam Block's images at www.Astronomy.com/toc.

A bit more information

Interested in learning more about Adam Block, the SkyCenter, or the institution that runs it? Then check out these web sites:

Adam Block's personal home page:
http://www.caelumobservatory.com

Mount Lemmon SkyCenter site:
http://skycenter.arizona.edu

Steward Observatory:
http://www.as.arizona.edu

University of Arizona College of Science:
http://cos.arizona.edu

The Hercules Cluster (M13) has an apparent magnitude of 5.8 and is visible with the naked eye from a dark site. To see detail like this, however, you'll have to break out the telescope.
Adam Block/Sid Leach/Mount Lemmon SkyCenter/University of Arizona

Explore the Gem of the Milky Way

Summer's Scutum Star Cloud holds numerous observing treats for any size telescope. **by Alan Goldstein**

The saying, "Good things come in small packages," holds true for the tiny constellation Scutum the Shield. It's tucked between Aquila to the northeast, Sagittarius to the south, and Serpens Cauda to the west. Scutum ranks as one of the smallest constellations (number 84 out of 88), yet its 109 square degrees contain enough objects to keep serious deep-sky observers busy for hours.

Scutum is also the smallest constellation with its own star cloud, which is a region where star density is high. A star cloud is actually part of one of the Milky Way's spiral arms that curves away from us. The star cloud's pearly glow is due to the vast number of stars situated in the center of the spiral arm. The galactic plane (the Milky Way's equator) bisects this constellation.

Edward Emerson Barnard (1857–1923) called Scutum the "Gem of the Milky Way" because of its richness within a compact area. Like the sparkling beauty of a cut diamond that scatters light from its many facets, the Scutum Star Cloud has many facets for deep-sky observers to discover. You can enjoy noteworthy views with the naked eye, binoculars, or any telescope.

Open clusters galore

Many extend Barnard's analogy and claim the **Wild Duck Cluster**, or M11 (NGC 6705), is the "Gem within the Gem." Astronomers estimate the group contains some 2,900 stars, with about 500 brighter than 14th magnitude. The combined starlight is equivalent to a "star" slightly brighter than 6th magnitude, making the cluster readily visible to unaided eyes under dark skies. The brightest stellar members are about 8th magnitude, but they are hard to distinguish in binoculars or a finder scope because of the cluster's rich density.

M11's nickname comes from the 19th-century English amateur astronomer Admiral William Henry Smyth, who described M11 as a "flight of wild ducks."

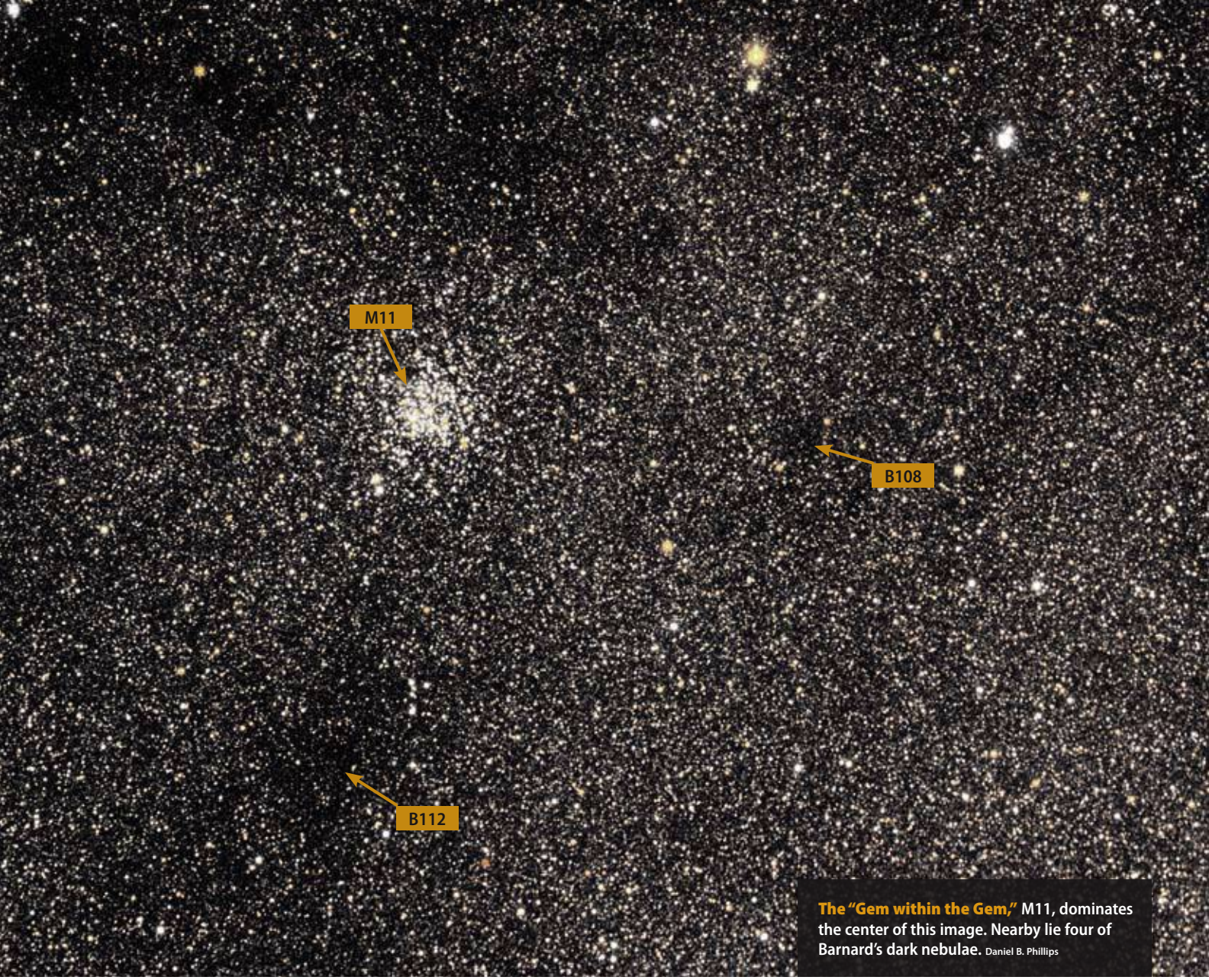
You might notice that one edge forms something of a "V" shape. I would describe it more as a flight of sandhill cranes because I have seen them flying overhead in flocks as large as 400 to 500 birds. For observers who enjoy making accurate sketches of deep-sky objects, start early because this will take all night!

In a rich star field within the Scutum Star Cloud lies **M26** (NGC 6694), a bright cluster about 14′ in diameter. In a modest scope, you'll see two dozen stars, but you'll need a larger scope to resolve another 70 cluster members.

NGC 6649 is the only Scutum star cluster located in front of a large dusty area that stretches southwest to the

Scutum's lone globular cluster (NGC 6712) lies roughly ½° southeast of the planetary nebula IC 1295. This pair forms a nice comparison in a large telescope. Chris Schur

Alan Goldstein, *a long-time contributor to* Astronomy, *has been observing since 1973.*



The "Gem within the Gem," M11, dominates the center of this image. Nearby lie four of Barnard's dark nebulae. Daniel B. Phillips

reflection nebula IC 1287 and northeast to **B314**. Compact cluster NGC 6649 contains some 50 stars 10th magnitude and fainter in a nearly 6.5'-wide area. Through a 4-inch scope, it looks nebulous, but it's well-resolved in a 6-inch.

Centered about ½° east of Alpha (α) Scuti in a broad swath of sky riddled with dust clouds lies **NGC 6664**. This magnitude 7.8 loose cluster is brighter than M26. Even through a 2-inch telescope, you'll see its brightest stars. Through larger scopes, about 50 stars appear spread across a 16' field. Some observers note the brightest stars form an "M" or "U" pattern. What do you see?

A 6-inch telescope will resolve **NGC 6704**, a compact rich cluster, but you'll need an 8-inch instrument to see much more detail. This cluster contains more than 25 stars fainter than 12th magnitude in an area less than 6' across.

The lone globular

NGC 6712 is the only globular cluster in Scutum. It glows at magnitude 8.2, and you can see it through binoculars under a dark sky. Some say a 6-inch scope will resolve the brightest stars, but others claim you'll need an aperture of 10 inches. What size scope do you need? (With my sky conditions in the Ohio Valley, I lean toward the larger size.)

This globular's main claim to fame is its apparent proximity to (about 1.5' west of) the planetary nebula **IC 1295**. While this nebula is fainter than the famous Ring Nebula (M57) in Lyra the Lyre, it's slightly larger at 86" across. Telescopes as small as 6 inches in diameter will show its disk shape. With a larger scope, the irregular nature of the nebula becomes more apparent.

The globular cluster is actually 22,500 light-years from us — more than 6 times farther away than the nebula. The fact that we can see both is a happy coincidence. NGC 6712 lies far beyond the star cloud and is actually visible through the intervening starlight and dust.

The realm of the nebulae

Scutum's brightest nebula is **IC 1287**. This reflection nebula surrounds the binary star system Struve 2325, a pair of 6th- and 9th-magnitude stars separated by 12.4". Photographs of the nebula show a bluish glow typical of light from hot blue stars reflecting off nearby dust. Filters used to enhance emission nebulae will

Bernhard Hubl

The bright reflection nebula IC 1287 and open cluster NGC 6649 sit in the same field of view in this image. IC 1287 is Scutum's brightest nebula.

Open cluster M26 consists of a tight core that's readily visible in a moderate-sized telescope. To view the fainter members, however, you'll need to break out a larger scope. Lee C. Coombs

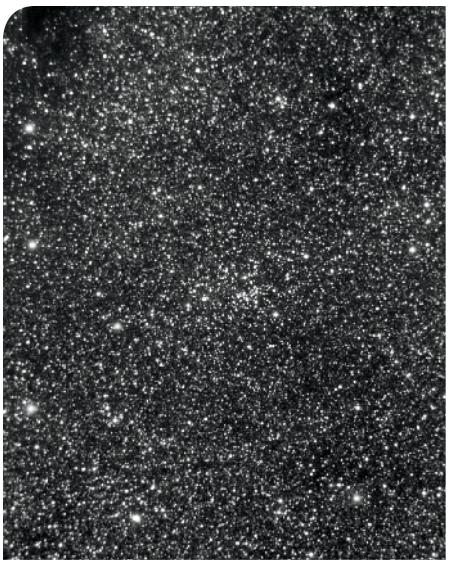
Observing targets in the Scutum Star Cloud

Object	R.A.	Dec.	Mag.	Size	Type
IC 1287	18h30.4m	–10°48'	—	20'	RN
NGC 6649	18h33.5m	–10°24'	8.9	6.6'	OC
NGC 6664	18h36.6m	–8°13'	7.8	16'	OC
B314	18h37.7m	–9°37'	—	35' by 25'	DN
PK 23-2.1	18h43.3m	–9°05'	12.4	4"	PN
M26	18h45.3m	–9°23'	8.0	14'	OC
B108	18h49.6m	–6°09'	—	3'	DN
B318	18h49.7m	–6°24'	—	90' by 2'	DN
B110	18h50.1m	–4°48'	—	11'	DN
B111	18h50.6m	–4°57'	—	2°	DN
NGC 6704	18h50.9m	–5°12'	9.2	6'	OC
M11	18h51.1m	–6°16'	5.8	13'	OC
B112	18h51.2m	–6°40'	—	20'	DN
NGC 6712	18h53.1m	–8°42'	8.2	7.2'	GC
B114	18h53.2m	–6°48'	—	6'	DN
B115	18h53.3m	–6°40'	—	7' by 1.4'	DN
B116	18h53.5m	–7°12'	—	—	DN
B117	18h53.7m	–7°27'	—	1'	DN
B118	18h54.0m	–7°27'	—	2'	DN
IC 1295	18h54.6m	–8°50'	13.5	86"	PN

R.A.=Right ascension (2000.0); Dec.=Declination (2000.0); Mag.=Apparent magnitude; DN=dark nebula; GC=globular cluster; OC=open cluster; PN=planetary nebula; RN=reflection nebula

not work with this object. You'll need transparent and dark skies to view it.

The Milky Way is dense with planetary nebulae, and the Scutum Star Cloud is no different. Unfortunately, most of the nebulae are small (less than 8" across) and faint (nearly 14th magnitude). The typical observer will find almost all planetary nebulae challenging, and each will show a nicer view if you use an Oxygen III (OIII) filter.



Martin C. Germano

The compact open cluster NGC 6704 spans an area smaller than 6' across. It's hard to make out the cluster from the background star cluster.

PK 23–2.1 (M1–59) is a small and relatively bright planetary nebula. You can view the nebula using a 6-inch scope, but it appears stellar because it's only 4" wide. The best way to find it is to "blink" it with an OIII filter. By passing the filter between your eye and the eyepiece, the nebula will appear brighter and the background stars dimmer. It's in a line of stars about ½° northwest of M26 and about 2' east of the variable star Delta (δ) Scuti.

Lost in the dust

Certain parts of the star cloud are brighter than others due to the dust patches commonly found within the galactic plane. Photographs of the **Scutum Star Cloud** show the nearly two dozen dark, dusty nebulae Barnard cataloged in the early days of astrophotography. The **B111/B320 Complex** is the largest, spanning 2°. **B117** is the smallest and spans a mere arcminute. A telescope with a field of view between 2° and 5° will provide the most spectacular view of these objects. Any moderate to large scope with a field of more than 1° will provide an appealing view of the more compact dust clouds and the edges of the larger, more pronounced ones.

Scutum's most compact dust clouds include **B108**, **B110**, **B112**, **B114**, **B115**, **B116**, **B117**, and **B118**. They stand out superimposed over the uncountable number of stars that make up the Scutum Star Cloud's eastern side. Farther south is a broad dust cloud 1° east-northeast of open cluster M26 in a line between that cluster and the globular cluster NGC 6712. Perhaps the most unusual dust cloud is **B318**, which forms a dark linear feature nearly ¾° long immediately below M11.

The densest star fields begin 1° north of Epsilon (ε) Scuti and stretch farther north for 2°. Their density decreases slightly before terminating near Beta (β) Scuti. An "anti star cloud" (a large dust cloud) just over the constellation border in southern Aquila (near the stars 7 and 8 Aquilae) cuts off the Scutum Star Cloud's northern edge. The Aquila dust cloud and one to Scutum's west in Serpens Cauda create contrast that makes the Scutum Star Cloud appear even more prominent under a dark sky.

Bang for the buck

Make the area around the Scutum Star Cloud a target for your next observing session. You can see a part of our galaxy where the beautiful and the obscure, the bright and the dark, mingle. Nice things do come in small packages.

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The **Astro-Tech AT8RC** is the only 8" true R-C from a U. S. supplier. It is ideal for imaging with large format (STL-type) CCDs and long imaging equipment trains. It has a *carbon fiber tube, low expansion quartz mirrors, dielectric mirror coatings,* 1/12th wave or better optics, and more. The AT8RC is now shipping at its new lower price of only **$1395**

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Meade 6" ETX-LS

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And you don't need to take a computer outside to take deep sky photos with the ETX-LS. The sensitive CCD camera under the optical tube stores 8° wide-field images on an optional SD card to view inside on your computer later or you can see them immediately using the scope's video output and an optional monitor.

Astronomer-Inside™ software guides you to the best objects in the night sky while a built-in speaker delivers a celestial encyclopedia of audio and video content to take you on an interactive guided tour of hundreds of night sky objects.

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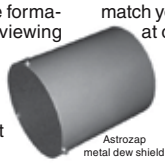
4 output/2 channel AstroZap controller



Astrozap metal dew shield

Astrozap dew shields slow the formation of dew that can shorten your viewing time and ruin your photos.

Black felt-lined flexible black plastic Astrozap dewshields start at only $24.95, making the flexible Astrozap dew shields our most economical dew protection.

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The new Astro-Tech Paradigm *Dual ED* eyepieces. Once again, more performance for less money.

Paradigm 1.25"

$79.95

With Astro-Tech eyepieces, you see more, but spend less!

At $79.95 each, the new 60° field 5, 8, 12, 15, 18, and 25mm **Astro-Tech Paradigm Dual ED** 1.25" 6 element/4 group eyepieces have *two* ED elements for sharp, flat field images that will have you wondering why other eyepiece brands cost so much more.

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The Astro-Tech Voyager – "a really sweet grab-and-go."

Astro-Tech Voyager with optional Cloudy Nights "2007 Gear of the Year" Astro-Tech 4" AT102ED

$299

A recent review said that the $299 **Astro-Tech Voyager** altazimuth mount was "unusually stable for its size and weight" and that it was packed with "lots of first-class engineering" that made it "a really sweet grab-and-go setup that's ideal for viewing day or night."

The review praised the Voyager's "smooth slow motion controls . . . Couple them with the Voyager's stability, and it was a pleasure viewing at magnifications approaching 200x – something I can't say for most alt-azimuth mounts that you have to push by hand."

The Voyager holds 20 lbs, has dual automatic clutch worm gear manual slow motion controls, adjustable height aluminum tripod, Vixen-style dovetail, and a very affordable price.

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41mm Panoptic – 2", 68° **510**
Nagler Type 6 – 1.25"; 82°; 2.5, 3.5, 5, 7, or 8mm **290**
31mm Nagler Type 5 – 2"; 82° **640**
2-4mm Nagler zoom – 1.25"; 50° **395**
8mm Ethos – 1.25"/2", 100° **585**
17mm Ethos – 2", 100° **750**

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Discover the sky's deepest, darkest secrets

Over three dark nights in southern Arizona, two observers track down dozens of the sky's most exotic objects. **by Michael E. Bakich**

I've been an amateur astronomer for more than 40 years. When I settle down to observe the deep sky, I expect to have a great time. I don't want weather and lights to be issues.

My boss, *Astronomy* Editor David J. Eicher, feels the same. That's why we traveled to Rancho Hidalgo Astronomy Village in Animas, New Mexico, last October. This site boasts an unbeatable combination of moderate temperatures, generally cloud-free weather, good elevation (4,600 feet [1,400 meters]), and a pitch-black sky. Oh, and there's developer Gene Turner's 30-inch f/4.3 Starmaster reflector — the icing on the cake.

Dave and I jetted into Tucson, Arizona, and rented a car for the 2-hour drive to Animas. We then had 3 nights filled with some of the most incredible observing either of us has ever had.

If you're observing in the fall, why not target NGC 1, the first object in the *New General Catalogue*? This small spiral galaxy shines at magnitude 12.8. Another spiral, NGC 2, which lies below NGC 1 in this image, glows a magnitude and a half fainter. R. Jay GaBany

Developer Eugene Turner (left) poses with *Astronomy*'s Editor David J. Eicher in front of Turner's 30-inch Starmaster Dobsonian-mounted Newtonian reflector. The 30-inch go-to telescope is the one with which we made all the observations in this story. Michael E. Bakich

With a 30-inch scope at our disposal under pristine skies, neither of us wanted to revisit the "same old" targets. So, we came up with a list that included objects we couldn't see well through an 8-inch telescope ... or a 12-inch ... or a 16 ...

Let the observing begin

Turner acted as our "driver." As we chose each target, he keyed it in to the Starmaster's computerized go-to drive. When the scope stopped moving, Turner climbed the ladder to verify the object was in the field of view.

Throughout the 3 nights, a cadre of amateur astronomers observed with us. Some were residents of Rancho Hidalgo, while others lived in Turner's other development, Arizona Sky Village, located in Portal, Arizona. Joining us each night

Open cluster NGC 7789 in Cassiopeia is a moderately bright cluster through a small telescope. When we viewed it through the 30-inch telescope, however, the field of view exploded with hundreds of stars. Our eyes formed many patterns and perceived dark lanes that filled the spaces between lines of stars. Lee C. Coombs

Try to ignore the bright star, and concentrate on Mirach's Ghost (NGC 404). What makes this 10th-magnitude elliptical galaxy a challenge object is its proximity to Mirach (Beta [β] Andromedae), which shines more than 1,500 times brighter, at magnitude 2.0. Anthony Ayiomamitis

NGC 147 in Cassiopeia is a dwarf galaxy that is a satellite of the Andromeda Galaxy (M31), although it strays nearly 7.5° from its parent. Normally difficult to observe because of its low surface brightness, NGC 147 stood out well at low power through the 30-inch. Anthony Ayiomamitis

were homeowners Adam and Tracy Clayson. I met them in April 2005 on a tour I led to view the total solar eclipse from the South Pacific. I admit to being envious of their observatory, which houses a 30-inch f/4.5 Obsession reflector.

Other notables were friends Jack and Alice Newton and comet-discoverer Stuart Wilson. Jack Newton is one of the world's premier astroimagers and a longtime contributor to *Astronomy*. While he mainly uses his own impressive observatory to hunt for supernovae, Jack and I did enjoy one early evening binocular hunt of dark nebulae in Aquila.

Wilson is renowned for his discovery of Comet 1961V (Wilson-Hubbard). He saw it near the star Tau (τ) Geminorum while piloting a Pan American 707 jet from Honolulu to Portland July 23, 1961.

The first night

After a wonderful dinner that Turner's partner, Loy Guzman, prepared, Gene, Dave, and I ventured outdoors. A quick visual scan showed the transparency (sky clarity, measured by the faintest star visible) was excellent and the seeing (the atmosphere's steadiness) superb. I detected no visible twinkle in any star more than 30° high. The telescope, which Turner set up earlier, had cooled to ambient temperature and was ready to go.

Before we could get to our list, Turner aimed the scope toward several bright deep-sky objects. His goal was to fine-tune the go-to drive, but a 30-inch scope pointed at any target is something I'll

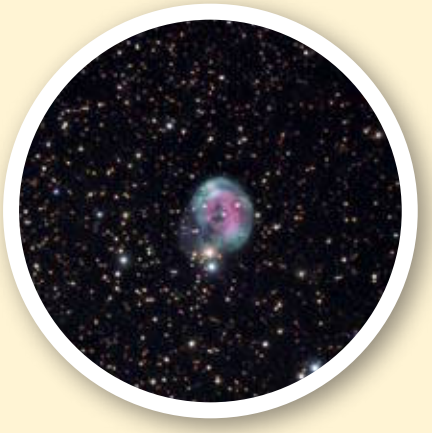
NGC 1491 in Perseus is a small emission nebula that looks like a tiny, faint fan — well, faint through most telescopes. What we saw was a vivid wedge of nebulosity streaked by dark markings and surrounded by a barely perceptible, irregular cloud of gas. Chris Schur

The Fireworks Galaxy (NGC 6946), at magnitude 8.9, was one of the brightest objects we observed during our 3 nights at Rancho Hidalgo in Animas, New Mexico. Although its size gives it a low surface brightness, the 30-inch Starmaster reflector revealed all of the galaxy's spiral arms. The galaxy's common name comes from the large number of supernovae discovered in it. Dietmar Hager

The Gamma Cassiopeiae Nebula (IC 59 and IC 63) is more a target for cameras than for the human eye. We were determined to observe both parts, however, and there they were! IC 59 is the topmost arc of nebulosity, and IC 63 is the denser wedge to the upper left of magnitude 2.5 Tsih (Gamma [γ] Cassiopeiae). We did not use a nebula filter, but one would have helped. Bernhard Hubl

Three named planetaries that look great through a 30-inch scope

The Blue Flash Nebula (NGC 6905) in Delphinus lived up to its colorful name. We easily saw features I have struggled to see through 16-inch telescopes. The central star and the two bright disk areas east and west of it were easy to see. And each of us could discern the striking blue color with both direct and averted vision. Al Kelly



The Fetus Nebula (NGC 7008) in Cygnus is well-named. This planetary's ring is open, irregular, and clumpy. It was also huge — more than 1' across. The nebula glows at a respectable magnitude, 10.8, but its surface brightness is low. We saw both the relatively bright star near its edge and the nebula's central star. Dietmar Hager

The Saturn Nebula (NGC 7009) in Aquarius took us to a new level for planetary nebulae. Both David Eicher and I commented that it was our finest view of this object ever. Whether it be NGC 7009's disk, its "wings," or the faint bulbs at the ends of the wings, we saw it all. The nebula also shone distinctly bluish-green. Daniel Verschatse/Observatorio Antilhue, Chile

never ignore. I climbed the ladder and there, in all its glory, was the Ring Nebula (M57). Although not a challenge object itself, the Ring's 15th-magnitude central star certainly is. After switching to a 9mm eyepiece (419x), it popped into view. Already we'd recorded a challenge object that wasn't even on our list.

Seeing the Ring Nebula prompted us to move several other planetary nebulae to the top of our list. First was NGC 6781 in Aquila. This object is much larger than M57, and it has a lower surface brightness. It didn't appear faint through the 30-inch scope, however. We easily traced the irregular outer ring, which surrounds a brighter central region. There, within the cosmic bubble, sat the magnitude 16.8 central star.

Four more planetaries followed NGC 6781 in quick succession. The Blue Flash Nebula (NGC 6905) in Delphinus began the short parade. Next were the Fetus Nebula (NGC 7008) in Cygnus, the Saturn Nebula (NGC 7009) in Aquarius, and (one of my favorites) the Bow-Tie Nebula (NGC 40) in Cepheus. This last object impresses observers because of its high surface brightness, and Turner's huge telescope revealed bright knots of gas and the dark region around the central star.

Other first-night highlights included several faint star clusters and spiral galaxy NGC 1. Any time I observe the fall sky, I target NGC 1, the first of 7,840 entries in Dreyer's *New General Catalogue*. Even the 30-inch didn't reveal much detail in this object. We also noted fainter NGC 2 less than 2' to the south.

Galaxy cluster Abell 426 in Perseus occupied our observing time for quite a while. Through the 30-inch reflector, each of us in turn counted dozens of members within this cluster. The brightest, irregular galaxy NGC 1275, glows at magnitude 11.9. Jeff Cremer/Adam Block/NOAO/AURA/NSF

The second night

On the second night, we decided to go after some really faint stuff. Turner again targeted a few well-known objects to check the go-to drive's accuracy. It was spot-on, so we headed for the night's first challenge, irregular galaxy IC 10 in Cassiopeia. This 11th-magnitude Local Group member would appear brighter if it weren't for one of the Milky Way's spiral arms lying between us and it. IC 10's large size also reduces its surface brightness, making it a tough catch through most scopes. And even through the 30-inch Starmaster, it didn't stand out well. But we saw it. Check one.

Michael E. Bakich *is a senior editor for* Astronomy *and a future Southwestern observer.*

Next up was the Gamma Cassiopeiae Nebula, a complex of faint emission nebulosity. The brightest patches are IC 59 and IC 63. This region would have been easier to see if any of us had thought to bring a nebula filter. Still, 30 inches of aperture captures a lot of light, and both nebulae were apparent to all observers.

The Perseus galaxy cluster followed. Turner targeted its brightest member, spiral galaxy NGC 1275. We saw it easily along with several dozen fainter galaxies. The ease with which we visually picked up so many of these faint fuzzies was a testament to the scope and the sky.

Other well-liked targets were NGC 147 and NGC 185. While these dwarf galaxies lie in Cassiopeia, both are satellite galaxies of the Andromeda Galaxy (M31). Planetary nebula Pease 1, which lies within the globular cluster M15, stood out well despite our lack of a nebula filter. Giant elliptical galaxy Maffei 1 wasn't bright, but just spotting it sent chills down my spine.

Bright galaxies in the constellations Sculptor and Cetus balanced out the many faint fuzzies we observed. The Southern Pinwheel Galaxy (NGC 300), NGC 247, the Silver Coin Galaxy (NGC 253), and the Southern Cigar Galaxy (NGC 55) looked terrific. Dave and I agreed the views we had of these giants were the best of our lives.

The final night

After the Sun set on the third evening, a cloudless blue sky gradually darkened to the color observers love — jet black. Broken in thousands of places by untwinkling stars and divided by the remnants of summer's Milky Way, the sky let us know we were in for another great night.

Dozens of faint objects crossed our field of view, but the ones that made the biggest impressions were galaxies. We gasped at the Fireworks Galaxy (NGC 6946). What appears as patternless fuzz around a bright center through small scopes resolved into four spiral arms dotted by patches of nebulosity.

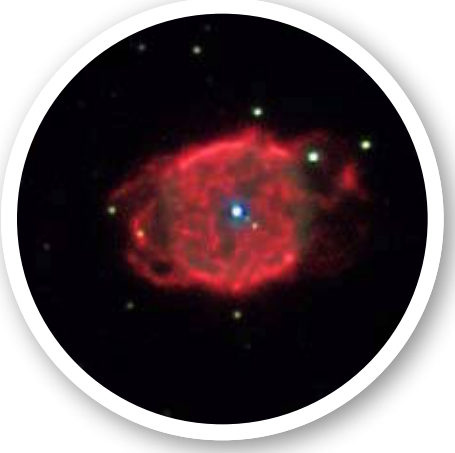
Two famous galaxy groups also highlighted the evening. The Deer Lick Group's brightest member, NGC 7331, showed amazing spiral structure. Of the other galaxies visible in the field of view, the three that form an equilateral triangle to the east stood out best.

Spotting Stephan's Quintet (NGC 7317, NGC 7318A, NGC 7318B, NGC 7319, and NGC 7320) isn't difficult. The challenge is to discern detail in the five member galaxies, and the 30-inch Starmaster proved its mettle. From the brightest of the quintet, NGC 7320, to the faintest, magnitude 15.3 NGC 7319, bright galactic cores, seemingly involved stars, and distorted spiral arms captured our attention throughout the night.

We awoke late the next morning fulfilled but saddened. We had to leave this observer's paradise and head back to the Midwest, to home, and to work. Don't get me wrong, this is a great job. I just wish it were closer to Rancho Hidalgo.

See more trip images and videos at www.Astronomy.com/toc.

The Cocoon Nebula (IC 5146) in Cygnus was not a difficult catch for the 30-inch Starmaster reflector. What proved more difficult, however, was the 2°-long, 20'-wide dark lane that stretches to the west from IC 5146. I mused that it looked like a freshly paved asphalt highway covering myriad stars. Michael Stecker



The Bow-Tie Nebula (NGC 40) is a favorite target of mine. The 30-inch scope revealed a huge, bright disk. We easily observed the object's outer knots. The magnitude 11.6 central star shone steadily, and a dark cavity surrounded it. Steve and Paul Mandel/Adam Block/NOAO/AURA/NSF

Lenticular galaxy NGC 1023 in Perseus showed many details through the 30-inch scope. The swirling gas appeared to swamp the nearly stellar nucleus. As we cranked up the power, there on the galaxy's eastern edge was NGC 1023A embedded in NGC 1023's halo. Ken Crawford

Planetary nebula NGC 6781 in Aquila was a nearly 3-D showpiece through the 30-inch scope. Even without a nebula filter, we easily traced the structure in its outer ring, noting how it broke to the north, gradually fading into the background sky. Adam Block/NOAO/AURA/NSF

Equipment review

Orion's low-cost APO delivers sharp images

The new EON refractor is affordable, portable, and well-built.

by Mike D. Reynolds

The front lens of the EON 80mm has a focal length of 500mm and a focal ratio of f/6.25. A retractable lens shade blocks stray light and protects the objective from dew.

Today's telescope market offers observers an excellent selection of small instruments. Count among them the EON 80mm ED Apochromatic Refractor Telescope from Orion Telescope and Binoculars based in Watsonville, California. Apochromatic refractors, or APOs as amateurs call them, employ up to four lens elements produced from extra-low dispersion glass and/or fluorite. Because APOs show fewer optical defects than other refractor designs, manufacturers often produce them with shorter focal ratios.

The basics are sound

With a focal ratio of f/6.25, the Orion EON 80mm APO is a reasonably fast telescope. It has a 500mm focal length, one which makes most short-focal-length eyepieces rate as medium power in this telescope. (For example, a 5mm eyepiece would yield 100x.)

The optical tube comes packed in a protective aluminum carrying case. This handsome new telescope includes a high-quality 2" Crayford focuser with dual-speed focus knobs. Fine focus operates at an 11:1 ratio, meaning one rotation of that knob equals 1/11 the rotation of the main focus knob.

The telescope also comes with a retractable lens shade, a dovetail mounting bar, and a finder scope base (also with a dovetail mount) that accepts all of Orion's finder scopes. The dovetail mount can be reversed for better balance.

Orion also placed two ¼-20 tapped holes in the bottom of the telescope's dovetail mount, making it easy to attach the mount to a camera tripod. The EON 80mm APO weighs in at only 6.5 pounds (3 kilograms), a manageable weight for light-duty telescope mounts or for when you travel.

Along with being user friendly, the EON 80mm APO is manufactured to high quality. The retractable lens shade, which allows for less length when the scope is in storage or transit, moved with ease and did not bind. A lens shade on a refractor is essential not only to block stray light but also to prevent dew forming on the objective.

Mike D. Reynolds, *a contributing editor of* Astronomy, *is the Dean of Liberal Arts and Sciences at Florida Community College.*

A protective aluminum case comes with the EON 80mm refractor. It seals well for storage and contains plenty of foam to protect the scope when you transport it.

Specifications

Orion EON 80mm ED Apochromatic Refractor Telescope

Type: Apochromatic refractor
Aperture: 3.15 inches (80mm)
Lens: Air-spaced ED doublet, fully multicoated
Focal length: 500mm
Focal ratio: f/6.25
Focuser: 2" Crayford, dual-speed (11:1)
Weight: 6.5 pounds (3 kg)
Included: Retractable dew shield, dovetail base, 1¼" eyepiece adapter, hard case
Price: $699.95

Pleiades: Tony Hallas; Moon: Lunar and Planetary Institute

The EON 80mm Apochromatic Refractor from Orion Telescopes and Binoculars is an affordable telescope that provides excellent images.

All equipment images: *Astronomy*: William Zuback

The telescope is well-baffled, and even the focuser's drawtube has machined threads. Orion scribed the drawtube in millimeters, allowing an observer or imager to reliably refocus.

A standout focuser

I liked the 2" dual-speed Crayford focuser. The action was smooth for either speed. Two speeds are a plus that astro-imagers will appreciate because they continually make fine focus adjustments. And, if you're a visual observer who's also a compulsive focuser like me, you'll come to love this feature as well.

To test the focuser's sturdiness, I mounted my Canon EOS 20Da to it with a standard T-ring mount and prime-focus adapter. I found no drawtube slippage or camera tilting. The focuser's tension and lock screws worked well, and the unit smoothly rotated 360° even with the camera attached. The rotation motion locks via a tube-diameter ring.

I found this rotating feature useful, especially for placing the focuser at a comfortable position. Orion includes a 1¼" eyepiece adapter, and it and the 2" version include brass compression rings to securely hold eyepieces or accessories in place without marring the barrels.

Skytesting the optics

I observed several celestial objects with the EON 80mm APO, but I also like initially testing a telescope on terrestrial targets. This tells me a lot about how the scope functions, both optically and mechanically. All terrestrial images appeared sharp.

Then I turned the telescope toward the Moon. I observed both a nearly Full Moon and, later in the month, a crisp young crescent Moon. I found the focus sharp, and I detected no chromatic aberration (which appears as colored fringes around bright celestial objects).

In my experience, chromatic aberration is most noticeable with the Moon. I also often use filters, which have given me good results when observing the Full Moon. The EON 80mm APO performed well when I employed color filters.

Jupiter and Venus made an excellent pair in our evening skies while I was testing the scope, so I pointed the EON 80mm APO toward each of them. The telescope is a short-focal-length instrument and not a longer "planetary" telescope, which permits high magnifications. Still, the images were excellent even when I pushed the magnification beyond 175x.

Stars were sharp through the EON 80mm APO. I viewed the Pleiades star cluster (M45) and several double stars. I also took the opportunity to test the telescope on more diffuse deep-sky objects, such as the Andromeda Galaxy (M31). It looked superb at low magnification, as did the Orion Nebula (M42), another cosmic showpiece for small telescopes.

High praise indeed

When I travel to observe total solar eclipses, I take an 80mm scope with me for solar photography. Needless to say, I am rather selective in the telescope I take; nobody wants to lose such an opportunity because of poor equipment. I would happily choose the Orion EON 80mm APO for such an expedition. It is an affordable, high-quality telescope that provides excellent images.

Contact information

Orion Telescopes and Binoculars
89 Hangar Way
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[t] 800.447.1001
[w] www.telescope.com

A 2" Crayford focuser (with a 1¼" adapter) assures you'll get crisp images. The focuser rotates 360° and has a scribed drawtube, which allows imagers to reliably return to a specific focus.

Secret Sky

by Stephen James O'Meara

Fireballs from the Scorpion

Look for spring's bright and flaming meteors.

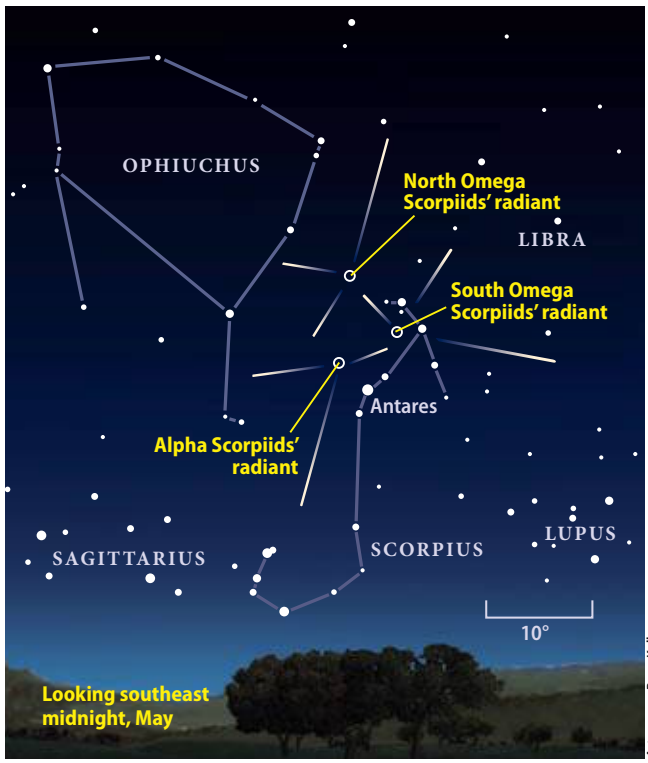
One activity I have long enjoyed this time of year is a fireball watch. If you're the kind of observer who can get excited about seeing one or two of these flaming "stars" in a month, then join me in trying to catch some Scorpiid meteors. They may be few, but they sure can be bright!

Scorpius has three radiants — the point in the sky from which meteors appear to stream — that spew meteors in May and June. They include the Alpha Scorpiids, which peak around May 16, and the Omega Scorpiid Complex, which has a north and south radiant and crests around June 2. But don't put all your effort into searching around only the peak dates. The meteors in these showers belong to very broad streams. You can see activity for weeks before and after the predicted maximums.

Unfortunately, one doesn't hear much about the Scorpiids in popular literature these days. When I was learning the sky in the 1960s, the Alpha Scorpiids at least were listed in my *Norton's Star Atlas and Reference Handbook* as an "important shower." And some sources still consider it a principal nighttime event. But today, both showers generally come and go with little, if any, noteworthy publicity.

Blame it on low zenithal hourly rates. The showers produce only about 3 to 5 meteors per hour at their peak. Certainly these numbers are low enough to turn some people off from looking … and waiting.

If you're after bountiful meteor numbers, the Scorpiids probably are not for you. But if you'd like to chance seeing a fireball, one that burns and spits flames across the sky for several seconds before vanishing, these showers might just interest you!



Astronomy: Roen Kelly

The Scorpiid meteor shower is actually two showers: the Alpha Scorpiids and the Omega Scorpiids. The Alpha Scorpiids' radiant is some 4.5° northeast of Antares. The Omega Scorpiids has two separate radiants, but its mean radiant is about 8° northwest of Antares.

Back-to-back Scorpiids

The Alpha Scorpiids are active from about April 21 until May 26, and, as mentioned, they peak around May 16. It's an interesting stream. Peter Jenniskens, a meteor expert with the Carl Sagan Center at the SETI Institute, says the Alpha Scorpiids move in very elongated orbits. The orbit reaches its closest approach to the Sun (called its perihelion) near Mercury's orbit and its farthest distance (called its aphelion) near Jupiter's orbit. Consequently, the meteors enter Earth's atmosphere relatively fast — at speeds of 21 miles per second (34 kilometers/s). The better-known Geminid meteors travel at 22 miles/s (35 km/s), so these two are closely matched.

The Alpha Scorpiid shower's radiant lies about 4.5° northeast of brilliant Antares, the blazing 1st-magnitude star that forms the red heart of Scorpius the Scorpion. For observers at mid-northern latitudes, this region of sky just peeks above the southeastern horizon around the time of sunset in mid-May. This situation is perfect for sighting Earth-skimming fireballs that overtake our planet from behind. Because of the glancing angle, it's common for Alpha Scorpiids to take long, lordly paths across the sky, flaming and spitting debris along the way. Some even make noise.

Indeed, the Alpha Scorpiid shower is best known for its eye-catching fireballs that exceed the brilliance of Venus, with magnitudes of –5 or brighter. They are brilliant enough to see in twilight or daylight, especially when the Sun is near setting. That's why I keep a leisurely vigil that begins around the time of sunset and continues at least until the stars come out.

The Omega Scorpiids skirt the Alpha Scorpiids and are active from May 23 to June 15. Its meteors share the visual splendor and physical characteristics of the Alpha Scorpiids, although they trundle through the atmosphere at speeds of only 12 miles/s (19 km/s). This is about 2 times slower than an Alpha Scorpiid meteor and almost 4 times slower than a

From sunset through dusk in May and June, look for a bright fireball coming from the direction of the Scorpion. While the Scorpiids have low hourly rates, they do feature burning bright meteors. Bristen Bourque

Many historic accounts of the Scorpiid meteors mention their green tinge. Watch for these green and bright fireballs. This particular meteor was an October Orionid. Stephen James O'Meara

Leonid (which travels at 44 miles/s [71 km/s])! The shower's mean center of activity lies about 8° northwest of Antares.

Bright lights

William F. Denning of Bristol, England, may have been the first to excite observers about the fireball-radiants in Scorpius. In an 1884 issue of *The Observatory*, he wrote: The "shower of June Scorpiids is evidently an important one. … The presence of the Moon is an objection; but neither moonlight nor the strong twilight of this season will materially affect the observation of these brilliant meteors."

Denning referred specifically to several memorable events that he wrote about in 1878. On June 7, 1878, observers across the United Kingdom saw three "very fine" meteors, two of which were visible in daylight. While both daylight meteors were unmistakable — one at about 5:15 P.M., the other at about 8:30 P.M. — the latter one was more widely spotted.

The Alpha Scorpiid shower is best known for its eye-catching fireballs that exceed the brilliance of Venus, with magnitudes of –5 or brighter.

According to various eyewitnesses, it was like a "globe of liquid fire" that moved very slowly across the sky toward the northwest horizon. Many saw it as pale green in color. Another witness, in Bath, "fancied he heard a crackling sound."

The third meteor of that night was visible around 9:50 P.M. One observer described it "like the light of a glow-worm highly intensified." As seen from Knole Park, near Bristol, the burning globe passed about 3° below the Moon, at which time "its brilliancy caused the moon to look of a muddy yellow colour, like a street lamp in a November fog." A correspondent at Clifton commented, "I have seen many meteors, but never any thing so large, of such brilliant colour [emerald green], and apparently so close to the earth."

Years later, in 1908, Denning wrote about the coincidence of three extraordinary fireballs from Scorpius. Two occurred in 1908: one on May 19, which "passed over Ireland from Ballyteigne Bay to Co. Mayo … along a path of 142 miles," and the other on May 22. The third, on May 19, 1906, was a "large meteor" from the same radiant, seen at Bristol and in Wales.

Denning concluded that meteor observers "will doubtless meet with further interesting instances of these brilliant summer Scorpiids in future years, and will find them amply repay attention."

Friendly fire

Do not underestimate the power of a fireball on one's soul. Seeing one might change a person's life. In 1986, at the age of 10, American Meteor Society observer Pierre Martin spent a clear summer evening in his backyard in Ottawa, Ontario, looking for shooting stars.

"The watch was uneventful at first," he recalls, "but near the end, I saw a dazzling fireball streaking high overhead. It left a thick train that persisted for several seconds. This event sparked the beginning of my long-lasting interest in meteor observing." Thanks to that summer fireball, Martin's primary interest continues to be visual meteor observing.

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by Michael E. Bakich

Russ **Lederman**

Vice President, Denkmeier Optical

Denkmeier Optical Vice President Russ Lederman has been an inventor for many years. He holds a patent on the Denkmeier Power Switch System and has a provisional patent for a binoviewer spotting scope.

Lederman was born in Toledo, Ohio, but grew up in Brooklyn. In his 20s, while reading an astronomy book, he saw amazing images. He decided to get a telescope and bought a 10-inch Meade LX3. He used it for 3 years before upgrading to his current instrument, a 20-inch reflector.

When he was younger, Lederman played guitar professionally. He was a solo act who played in small venues. He also worked as a dental technician, producing intricate ceramic bridgework. Such skills serve him well in his current position.

Lederman likes to say that he started as an amateur astronomer and "not as a professional peddler." Based on Denkmeier's success, he's excelled at both.

When Russ Lederman observes, he uses Denkmeier Optical binocular viewers. Image courtesy Russ Lederman; Moon image: C. R. Lynds, KPNO/NOAO/NSF

How did you start Denkmeier Optical?

I started the company in 2001 with a friend to produce binocular products. In July 2007, I purchased the company in full. I wanted to expand the product line, but trying to do design, assembly, and sales myself left little time for growth.

In what I call the third stage of our company, I merged with Spectrum Thin Films. Spectrum began in 1993 as a supplier of optics and optical coatings in Hauppauge, New York.

Since the merger, avenues for creating new products have expanded. With Spectrum's state-of-the-art production facility, coating machines, and a staff of 30, it's a lot easier to see our ideas bear fruit.

I also have a great business partner in Spectrum's president, Tony Pirera. Like me, he has an idea, assesses its merit, and, if it passes muster, he pursues it.

Tell me about Denkmeier's most popular products.

We sell more of our Power x Switch binocular viewing systems all over the world than any other product. These units have a Power x Switch incorporated into the binocular viewer.

Our stand-alone binocular viewer also is a great seller, as is our Power Switch Star Diagonal. So, a telescope that doesn't use a star diagonal must use the Bino-Mounted Power Switch. Scopes using star diagonals can choose to have the Power Switch incorporated into them or the binoviewer.

Tell me something cool about Denkmeier.

Although we are a business, Denkmeier is made up of people who love astronomy. We actually develop our products because we really want them, and we test them just like any amateur astronomer would.

Do you enjoy observing? Anything specific?

I like observing everything from the Moon to challenging deep-sky objects to daytime atmospheric effects like Sun dogs.

I began observing Palomar globulars through my 20-inch reflector, looking for galaxies that catalogs listed near their positions. When I found globulars but no galaxies, I contacted Brian Skiff at Lowell Observatory in Flagstaff, Arizona. Working with him, we cleared up those misidentified galaxies.

Can you share anything about upcoming products?

Our newest available products fall into our filter line: OIII, UHC, and a nice planetary filter. We are working on some really exciting new products, but I can't be too specific right now. We are developing a Hydrogen-alpha module to work in conjunction with our binoviewers that combines Tony's coating expertise with my Power x Switch design.

Where, in your opinion, is the hobby headed?

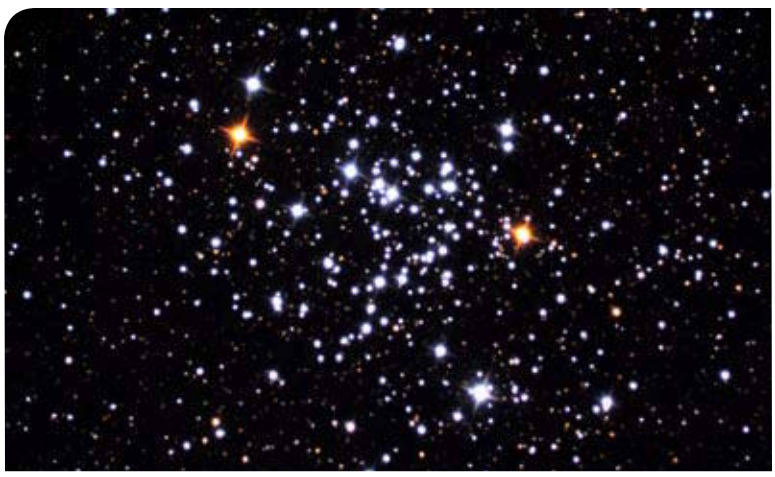
In order to get more people interested in amateur astronomy, we need to remove some of the pain involved in carrying out the hobby. By "pain," I mean, for example, traveling to remote dark sites with large telescopes and other equipment you need in order to see faint objects.

These are some of the things that keep people out of the hobby. I think that technology must make astronomy easier and, therefore, more rewarding.

I see 2009, the International Year of Astronomy, as pivotal. I'd like to see schools — even in cities — set aside a shielded area where students could observe the night sky on an ongoing basis. That would bring more people into our hobby.

reader gallery

Comet C/2007 N3 (Lulin) (4-inch Takahashi FSQ-106ED refractor at f/5, Apogee Alta U16M CCD camera, LRGB image with a 12-minute exposure through each filter, February 22, 2009, at 1:44 A.M. CST) • Phillip L. Jones, Frisco, Texas



The Pearl Cluster (NGC 3766) sits in the southern reaches of Centaurus, near Crux. It shines at magnitude 5.3. (12-inch Meade LX200 Schmidt-Cassegrain telescope at f/5, Starlight Xpress SXV-H9 CCD camera, LRGB image with 10-minute exposures through each filter) • Michael Sidonio, Googong, New South Wales, Australia

A green comet glows in the sky

Comet Lulin (C/2007 N3) attained naked-eye brightness in the evening sky in February. Its amazing dust and ion tails plus its bluish-green color thrilled astroimagers around the world. As Lulin moved through the constellation Leo the Lion, it appeared near Saturn. Then, a few days later, it brushed Regulus (Alpha [α] Leonis). At its closest to Earth, Comet Lulin moved 5° a day. That's a span it would take 10 Full Moons side-by-side to cover.

∨ This complex of dark nebulae in Aquila is seldom imaged by astrophotographers. In 1962, American astronomer Beverly Lynds published a catalog of dark nebulae. Each of the 1,791 objects she listed in her catalog now carries the designation "LDN," for "Lynds Dark Nebula." (4-inch Tele Vue NP101 apochromatic refractor, SBIG ST-2000XM CCD camera, LRGB image with exposures of 312, 108, 54, and 54 minutes, respectively) • Bernhard Hubl, Schlierbach, Austria

∧ Reflection nebula NGC 5367 in Centaurus lies 4° south-southwest of magnitude 2.1 Theta (θ) Centauri. The nebula's dust and gas (denoted Cometary Globule 12) dims light from the stars in the sparse cluster by about a magnitude. (8-inch ASA astrograph at f/3.8, FLI 6303E CCD camera, LRGB image with exposures of 70, 20, 20, and 30 minutes, respectively) • Gerald Rhemann and Michael Jäger, Farm Tivoli, Namibia

∧ The Running Chicken Nebula (IC 2948) is a bright emission nebula in Centaurus. This image shows a small part of IC 2948. The entire nebula spans 70 light-years and lies 6,000 light-years from Earth. (14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-11000M CCD camera, LRGB image with exposures of 105, 20, 20, and 20 minutes, respectively) • Andrew F. Macica, San Jose, California

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

The region of NGC 2170, which lies in the constellation Monoceros the Unicorn, is awash with nebulae. This area lies 1.8° west of magnitude 4 Gamma (γ) Monocerotis. Blue-colored clouds represent reflection nebulae, and red-hued ones are emission nebulae. For a labeled chart of this region, go to www.Astronomy.com/toc. (6.2-inch Astro-Physics 155EDF apochromatic refractor at f/5.4, FLI KAF-16803 Proline CCD camera, L/Hα/RGB image with exposures of 260, 300, 100, 100, and 100 minutes, respectively) • Thomas V. Davis, Inkom, Idaho

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